



DECLARATION

I, Yasuyuki Tanaka, of Kichijoji-Hirose Bldg., 5th Floor, 10-31, Kichijoji-honcho 1-chome, Musashino-shi, Tokyo 180-0004 Japan, Japan do solemnly and sincerely declare that I well understand both Japanese and English languages and the attached English version is a full, true and faithful translation of the certified copy of Japanese Patent Application No. 2001-019271 filed on January 26, 2001 in the name of FUJITSU LIMITED.

And I made this solemn declaration conscientiously believing the same to be true.

This 7 day of March , 2005

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(Page 1 of 2)

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[Title of Invention] METHOD OF READING INFORMATION AND APPARATUS THEREFOR, METHOD OF ACQURING SIGNAL FOR USE WITH INFORMATION READING APPARATUS, METHOD OF PROCESSING BAND LIMITATION, METHOD OF EXTRACTING TIMING POINT AMPLITUDE AND METHOD OF PROCESSING SIGNAL THEREOF, READ SIGNAL PROCESSING UNIT, AND METHOD OF PROCESSING READ SIGNAL AND PROCESSING APPARATUS THEREOF
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[Title of the Invention] METHOD OF READING INFORMATION AND APPARATUS THEREFOR, METHOD OF ACQURING SIGNAL FOR USE WITH INFORMATION READING APPARATUS, METHOD OF PROCESSING BAND LIMITATION, METHOD OF EXTRACTING TIMING POINT AMPLITUDE AND METHOD OF PROCESSING SIGNAL THEREOF, READ SIGNAL PROCESSING UNIT, AND METTHOD OF PROCESSING READ SIGNAL AND PROCESSING APPARATUS THEREOF

[Scope of Claim for a Patent]

[Claim 1] A method of reading information characterized by comprising steps of:

acquiring from a medium, a signal containing binary digit information having a predetermined information length and a one-dimensional arrangement;

extracting information concerning an elemental unit length of the information length of the binary digit information from the acquired signal; and

reading a ratio of the binary digit information to the information length based on the extracted elemental unit length information.

[Claim 2] A method of reading information according to Claim 1, characterized in that the elemental unit length information is extracted as an elemental frequency information corresponding to the elemental unit length, a band limiting processing is effected on the acquired signal based on the extracted elemental frequency information, and thereafter the ratio of the information length of the binary digit information is read.

[Claim 3] A method of reading information according to Claim 2, characterized in that a periodic signal is generated so as to be synchronism with the acquired signal and have an elemental frequency corresponding to the elemental unit length, whereby the elemental unit length information is extracted.

[Claim 4] A method of reading information characterized by comprising a step of acquiring a value from a signal containing binary digit information having a predetermined information length and deriving from information elements arrayed one-dimensionally on a medium at every equal time interval, wherein

when an elemental unit length of the information length of the binary digit information is extracted from the acquired signal, the portion of the signal for extracting the state of the binary digit information from the medium information has a band narrower than that of the characteristic for differentiation based on the equal time interval.

[Claim 5] A read signal processing unit characterized by comprising:

means for making extraction from a signal which is acquired from a medium, has a predetermined information length, and contains binary digit information deriving from information elements arrayed one-dimensionally on the medium, an elemental frequency corresponding to the elemental unit length of the information length of the binary digit information from the acquired signal; and

means for effecting a band limiting processing on the

acquired signal based on the extracted elemental frequency signal and thereafter extracting boundary information of said binary digit information.

[Claim 6] An information reading apparatus characterized by comprising:

a signal acquiring unit for acquiring from a medium, a signal containing binary digit information having a predetermined information length and an arrangement;

an elemental frequency extracting unit for extracting an elemental frequency corresponding to an elemental unit length of the binary digit information of the information length from the acquired signal;

a band limiting unit for limiting a frequency band of the acquired signal based on the extracted elemental frequency information;

a timing point extracting unit for extracting a timing point which is in synchronism with the acquired signal and has the elemental frequency, based on the acquired signal and the elemental frequency information;

an amplitude extracting unit for extracting an amplitude value of a signal from the band limiting unit in accordance with the timing point extracted by the timing point extracting unit;

a tri-state value generating unit for generating tri-state value data from the amplitude values extracted by the amplitude extracting unit in accordance with the timing point; and

a reading unit for reading a ratio of the binary digit information to the information length by calculating the

tri-state value data generated by the tri-state value generating unit.

[Claim 7] An information reading apparatus for reading information from a medium having a mark representing a data group composed of a predetermined number of pairs of information elements, each of the information elements being composed of a white region and a black region disposed alternately with a certain width arranged to have an association with coded data, the information reading apparatus acquiring the data group information as an integer number ratio between the data widths of each information element pair, the information reading apparatus comprising:

a signal acquiring unit for detecting an analog signal having a variation corresponding to an intensity variation of a reflected ray of light which is caused by scanning the mark on the medium with a ray of light running at a predetermined velocity in the scanning direction, and effecting a sampling operation on the continuous signal at a predetermined sampling frequency to acquire the data group information represented by the mark recorded on the medium in a form of digital signal;

an elemental frequency extracting unit for extracting an elemental frequency corresponding to an elemental unit length of the width of the white region and the black region from the acquired signal in the form of digital signal;

a band limiting unit for limiting a frequency band of the acquired signal based on the extracted elemental frequency information;

a timing point extracting unit for extracting a timing point which is in synchronism with the acquired signal and has the elemental frequency, based on the acquired signal and the elemental frequency information;

an amplitude extracting unit for extracting an amplitude value of a signal from the band limiting unit in accordance with the timing point extracted by the timing point extracting unit;

a tri-state value generating unit for generating tri-state value data from the amplitude values extracted by the amplitude extracting unit in accordance with the timing point; and

a reading unit for reading a ratio of the binary digit information to the information length by calculating the tri-state value data generated by the tri-state value generating unit, wherein

relationship among a width, bar[μm] of the white region or the black region representing the elemental unit length of the binary digit information, the scanning velocity, vmax[m/s] of the scanning ray of light, and the sampling frequency, fs[MHz] can be expressed by the following equation

$$2 < \frac{fs}{(2 * bar / vmax)} \leq 10.$$

[Claim 8] A method of acquiring a signal for use with an information reading apparatus having a signal acquiring unit for acquiring a signal containing binary digit information recorded on a medium so as to have a predetermined information length, the information reading apparatus being arranged to extract information regarding an elemental unit length of the information length of the binary digit information from the

acquired signal, thereby to read a ratio of the binary digit information to the information length based on the extracted elemental unit length information, the method of acquiring a signal for use with the information reading apparatus characterized in that

the signal acquiring unit acquires a signal containing the signal component and also a component other than one deriving from the medium having the binary digit information recorded thereon, determination is made on the acquired signal so as to identify a signal portion deriving from the medium having the binary digit information recorded thereon by using an amplitude averaging calculation processing, and

the signal component deriving from the medium is cut out in accordance with the result of determination, and the cut-out portion is acquired as a signal containing the binary digit information.

[Claim 9] A method of effecting a band limiting processing for use with an information reading apparatus having a signal acquiring unit for acquiring a signal containing binary digit information recorded on a medium so as to have a predetermined information length, the information reading apparatus being arranged to extract information regarding an elemental unit length of the information length of the binary digit information from the acquired signal, thereby to read a ratio of the binary digit information to the information length based on the extracted elemental unit length information, the method of effecting a band limiting processing for use with the information

reading apparatus characterized in that

as a preprocessing for reading the ratio data of the binary digit information to the information length, an elemental frequency corresponding to the elemental unit length is extracted from the acquired signal, and the frequency band of the acquired signal is limited based on the extracted elemental frequency.

[Claim 10] A method of extracting a timing point amplitude for use with an information reading apparatus having a signal acquiring unit for acquiring a signal containing binary digit information recorded on a medium so as to have a predetermined information length, an elementary frequency extracting unit for extracting an elementary frequency corresponding to an elementary unit length of the information length of the binary digit information obtained from the acquired signal, and a band limiting unit for limiting a frequency band of the acquired signal based on the extracted elemental frequency information, wherein a ratio of the binary digit information to the information length is read from the signal having undergone the frequency band limitation in the band limiting unit, the method of extracting the timing point amplitude for use with the information reading apparatus characterized in that

as a preprocessing for reading the ratio data of the binary digit information to the information length, a timing point in synchronism with the acquired signal and having the elemental frequency is extracted based on the acquired signal and the elemental frequency information, an amplitude value of a signal from the band limiting unit is extracted in accordance with the

extracted timing point, and tri-state value data is generated from the extracted amplitude values in accordance with the timing point.

[Detailed Description of the Invention]

[0001]

[Technical field pertinent to the invention]

The present invention relates to a method of reading information and an apparatus therefor, a method of acquiring a signal for use in an information reading apparatus, a method of processing band limitation, a method of extracting a timing point amplitude and a method of processing a signal thereof, a read signal processing unit, and a method of processing the read signal and a processing unit thereof, which are useful in a case when information contained in a bar code or the like is read with a bar code scanner, signal acquisition is made on a signal containing binary digit information deriving from information elements having a predetermined information length and arrayed one-dimensionally on a medium, and width information represented by binary digit amplitude information contained in the acquired signal is read in a form of integer number ratio.

[0002]

[Prior Art]

A manner of information registration has been conventionally employed in a field of merchandise distribution in which bar codes are attached to commodities and these bar codes are read by a bar code reading apparatus (bar code scanner) so that information concerning the commodity such as a price

or name thereof is registered in a register.

[0003]

The bar codes attached to the commodities and utilized in such situation are arranged in such a manner that the information concerning the ordinary commodities are coded and the coded information can be represented by an array of width information of respective black bars or white bars constituting the bar code. In the bar code reading apparatus, a beam of light is irradiated on such a bar code and coded data can be read from the intensity variation signal contained in the reflected beam of light (the intensity variation is dependent of a color of respective bars constituting the bar code).

[0004]

In a conventional bar code reading apparatus, a beam of light generated by an LD (Laser Diode) or the like is made to scan on a bar code, a reflected light ray deriving from the light beam is received and converted into an electric signal which makes it possible to detect the variation of the signal intensity, and thereafter, the width information of respective black bars or white bars constituting the bar code can be read as bar code information.

[0005]

FIGS. 58 and 59 are block diagrams showing a conventional bar code reading apparatus, for example. As shown in FIG. 58, a bar code reading apparatus (see U.S. Patent No. 5,061,843) is an apparatus for reading bar code information by carrying out a signal processing mainly composed of analog processing,

and arranged to include an optical scanning section 102A, and analog processing unit 102B and a digital processing unit 102C.

[0006]

According to the bar code reading apparatus shown in FIG. 58, a beam of light generated by an LD 102a-1 of the optical scanning section 102A is led to a polygon mirror 102a-2, and with the rotation of the mirror the beam of light is made to scan the bar code 102 in a direction from the left end to the right end thereof (in the figure, direction from a to b), for example, with the result that respective black bars or white bars are exposed under the beam of light.

The beam of light scanning the bar code 102 on the surface thereof is reflected with an intensity which corresponds to the width of the black and white bars constituting a pattern of the bar code. The intensity of the reflected light beam is dependent of the color of the respective bars of the bar code. That is, if the light beam reflects on a white bar then the light beam comes to have a relatively large intensity while if the light beam reflects on a black bar then the light beam comes to have a relatively small intensity.

[0007]

That is, when the laser beam is made to scan the bar code 102, the returning light comes to have a signal waveform which is characterized by having a small amount of luminous energy upon scanning a black bar while having a large amount of luminous energy upon scanning a white bar (see Sig 10, 50e, 50f in FIG. 60).

As for example shown in FIG. 60, the bar code reading apparatus introduces into the apparatus, an electric signal (see Sig 11) having an amplitude value which derives from detection on the above-described intensity variation of the reflected light beam (represented by reading of the signal Sig 10 on ordinate of FIG. 60), and thereafter the apparatus carries out a signal processing on the electric signal, whereby the bar code information can be read. The above-described signal processing is carried out in the following steps of (1) to (4).

[0008]

(1) A laser light beam generated from the LD102a-1 is made to scan the bar code 102 and the reflected light beam thereof is photo-electrically converted into an electric signal.

(2) In an analog processing section 102B, an amplifying unit 102c effects a necessary amplifying processing on the electric signal deriving from the photoelectric conversion, and thereafter the amplified electric signal is subjected to a differentiation processing in a one-time differentiating unit 102d. That is, the photoelectric converted signal is differentiated to obtain a differentiated signal waveform 50j (signal Sig 12) having a peak at a boundary between a white bar and a black bar. This signal is added with a minute time delay to create another signal 50k (signal Sig 13).

[0009]

This differentiated signal (signal Sig 12) and the signal having added with a delay by the delaying processing unit 102e (signal Sig 13) are compared with each other to form the

differentiated signal into an edge signal having an edge at a point corresponding to the peak in the differentiated signal. Then, the edge signal is converted into a digital signal. That is, a positive peak of the differentiated signal corresponds to an edge signal deriving from a change from a black bar to a white bar (WEG, see a signal Sig 14) while a negative peak of the differentiated signal corresponds to an edge signal deriving from change from a white bar to a black bar (BEG, see a signal Sig 15).

[0010]

In other words, when the signal 50j (Sig 12) and the signal 50k (Sig 13) are compared with each other by the comparator 102f, the edge signal WEG generated upon change from the black to the white and the edge signal BEG generated upon change from the white to the black can be obtained.

Meanwhile, in order to prevent an undesirable edge generation at a portion 50s in which no differentiating response is present, there is provided a circuit gating an edge signal which is created when the differentiated signal 50j stays within a constant rate level 50l of the differentiated signal 50j itself.

[0011]

(3) In a width measuring unit 102g of a digital processing section 102C, edge signal distances of a bar image signal (i.e., a distance between a BEG and a WEG sequel to the BEG and a distance between a WEG and a BEG sequel to the WEG) are measured by a count of a clock 102h or the like (see signal Sig 16). The clock 102h for measuring the time distance between the pair of edge

signals shall have a sufficient resolution.

[0012]

(4) In a module calculating unit 102i, a module number expressed as respective bar width data is calculated as a proportional calculation based on the count delivered by the width measuring unit 102g (see signal Sig 17).

Ordinarily, code information expressed as a width information on a bar code is composed of integer number ratio data having a predetermined length known as a module as an unit. Each of the bar has a width of an integer multiple of the above-described module. In this case, the integer number ratio is obtained based on the bar width value by the width measuring unit 102g so as to find the module ratio.

[0013]

Further, as shown in FIG. 59, an AD (Analog-Digital) converter 103d is provided to convert the acquired electric signal in the form of analog signal into a digital signal. The above-described signal processing shown in FIG. 58 can be carried out in the following steps of (1) to (5). According to the arrangement of the bar code reading apparatus shown in FIG. 59, signal processing is carried out in a digital manner in blocks corresponding to the blocks (see blocks identified by reference numerals 102d, 102e and 102f) of the aforesaid bar code reading apparatus shown in FIG. 58 in which the signal processing is effected in an analog manner.

[0014]

(1) Similarly to the case of the bar code reading apparatus

of FIG. 58, a laser light beam generated from an LD 103a-1 is utilized for scanning a bar code 103 by using the rotation of a polygon mirror 103a-2, whereby a reflected light beam from the bar code 103 is received by a light receiving unit 103b and an optical signal is photoelectric-converted into an electric signal.

(2) An amplifying unit 103c effects a necessary amplification processing on the electric signal supplied from the light receiving unit 103b, and thereafter the resulting signal is sampled in a digital manner by the A/D converter 103d or the like.

[0015]

(3) A digital signal from the A/D converter 103d having added with a time delay difference by delaying units 103e and 103f is subjected to a differential processing in differential processing units 103h and 103i.

That is, the differential processing unit 103h compares a signal from the A/D converter 103d and added with a delay time of t_2 and the same signal added with a delay time of t_1 with each other, and outputs a result as a compared result signal A. Further, the differential processing unit 103d compares a signal from the A/D converter 103d and added with a delay time of t_1 and the same signal added with no delay time t_0 with each other, and outputs a result as a compared result signal B.

[0016]

(4) A comparator 103i compares difference signals supplied from the differential processing units 103g and 103h

with each other so as to detect a point at which the largest variation is brought about and the output polarity is changed, and this point is outputted as an edge point.

(5) Similarly to the case of the width measuring unit 102g of aforesaid FIG. 58, a width measuring unit 103j counts a distance between edge points by using a clock 103k.

[0017]

[Problems that this invention is to solve]

In the conventional bar code reading apparatus shown in FIG. 58, however, if the bar code 102 has a blurred portion in printing, a concave-convex portion on the sheet of paper thereof (see portion shown at reference 50c in FIG. 60) or the like, for example, such portion will cause a distortion in a waveform representing the luminous energy of the returning light beam (see reference 50g), with the result that even in the differentiated signal two peaks having a positive value are created continuously (see reference 50h and 50i).

[0018]

If the edge signal is created from the differentiating signal, two edge signals of the same kind will be created continuously. Therefore, when the bar width is counted in a final step, it follows that the count is made by using a false edge. Consequently, the count indicating the bar width will have an error (50q, 50r) relative to the inherent true value (see reference 50o, 50p).

If calculation is made to obtain the integer number from the bar width value and the error is equal to or more than 0.5

module (in this example, the error is just equal to 0.5 module), erroneous recognition will be caused in the result of reading the bar code information.

[0019]

This erroneous recognition in the result of reading the bar code information due to the blur or the like on the bar code is mainly caused by the wide band characteristic of a circuit section including the light receiving unit 102b, amplifying unit and the differentiating unit, and the laser beam diameter. That is, as shown in FIG. 62, the arrangement of the bar code reading apparatus tends to have a characteristic that the scanning speed v is made slow to attain proper laser scanning at a window 57a while the depth of field for reading is made deep ($L \rightarrow$ large) to make the beam scanning speed v fast.

[0020]

That is, when a bar code is brought close to the window 57a to carry out reading operation, then a distance between the LD 102a-1 or the polygon mirror 102a-2 and the bar code will become relatively short and the depth of field for reading will become shallow ($L \rightarrow$ small). However, if the reading operation is carried out with the bar code remote from the window 57a, then the distance between the LD 102a-1 or the polygon mirror 102a-2 and the bar code will become relatively long and the depth of field for reading will become deep ($L \rightarrow$ large).

[0021]

Accordingly, as shown in FIG. 61, it is requested for the circuit characteristic to have a wide band characteristic capable

of covering from a low signal band (see reference 51b) in which the beam scanning speed is slow and the bar code to be read is large to a high signal band (see reference 51c) in which the beam scanning speed is fast and the bar code to be read is small.

[0022]

As a consequence, when a bar code having a relatively large magnitude is made to scan near the window surface, a minute laser beam will pickup the aforesaid printing blur or an abrasion to yield an erroneous recognition.

Moreover, as an influence from the beam diameter, for example, a light beam generated from the LD 102a-1 will be scattered as the depth of field for reading becomes deep. Thus, it becomes difficult for the light beam having a large diameter to accurately detect the reading bar code width with the reflected light beam thereof.

[0023]

What described above will be summarized as follows. That is, the above-described bar code reading apparatus shown in 58 encounters difficulties of (1) to (4) listed as follows.

(1) In order to make the apparatus capable of processing a bar code signal deriving from a reading operation effected at a depth of field for reading L which can extend from a shallow point to a deep point, a circuit on the receiving side is requested to have a wide band frequency characteristic. Therefore, the amount of noise will be increased as the band is set to be wide, which fact will cause a problem that a signal to noise ratio (S/N) will be deteriorated.

[0024]

(2) Since the apparatus is requested to read a fine bar code, the laser beam is also requested to have a thin diameter. In this case, if the bar code has a concave/convex portion on the sheet of paper thereof or a blurred portion or the like on the bar thereof, this concave/convex portion will be picked up and the signal will reflect the concave/convex portion. As a consequence, a boundary signal representing the boundary between a white bar and a black bar can be generated at a point other than the desired point. This fact can cause an erroneous recognition of an edge between the white bar and the black bar.

[0025]

(3) Since the scanning is made by a laser light beam, deeper the depth of field for reading becomes, wider the beam diameter. Thus, the laser light beam cannot provide high resolution, and hence there can be a case that to read a label of a fine bar code becomes difficult.

(4) When an edge signal is extracted, the signal will function as a bar image signal representing white or black of the bar code. In order to measure the width time of the bar image signal, the clock for counting the width time must have a time period short enough with respect to the bar width time. For this reason, a hardware operating at a high clock rate can become expensive and it might be requested to take a countermeasure against an EMI (electromagnetic interference).

[0026]

Also the above-described bar code reading apparatus shown

in FIG. 59 will encounter problems similar to those of (4) and (5) which are described with the aforesaid bar code reading apparatus shown in FIG. 58. In addition, the same bar code reading apparatus will encounter problems of (1) and (2) which will be described in the following.

(1) In order to keep a bar width accuracy, the A/D converter is requested to have a high sampling frequency (equal to or more than about ten times the minimum reading bar width). For this reason, the signal frequency band is increased and the reading system of the apparatus will become more sensitive to a noise caused by the above problem or a noise deriving from a circuit thereof. Thus, an edge between the white and black portions of the bar width can be erroneously recognized.

[0027]

(2) As described above, the data shall be sampled at a high rate. When the resulting data is utilized up to the final step, a processor is requested to have a high performance capable of processing a large quantity of sampled data. Moreover, a larger memory is also requested to store the large quantity of sampled data.

The present invention is made in view of the above aspect. Therefore, it is an object of the present invention to provide a method of reading information and an apparatus therefor, a method of acquiring a signal for use in an information reading apparatus, a method of processing band limitation, a method of extracting a timing point amplitude and a method of processing a signal thereof, a read signal processing unit, and a method

of processing the read signal and a processing unit thereof, which makes it possible to suppress the size of hardware and a price thereof and to improve an S/N ratio of a reading signal and reading resolution, wherein even if depth of field for reading is enlarged or a concave/convex portion or a blurred portion is left on the reading face, reading precision can be improved.

[0028]

[Means for solving the above problems]

According to the present invention, in order to attain the above objects, there is proposed a method of reading information characterized by including steps of acquiring from a medium, a signal containing binary digit information having a predetermined information length and a one-dimensional arrangement, extracting information concerning an elemental unit length of the information length of the binary digit information from the acquired signal, and reading a ratio of the binary digit information to the information length based on the extracted elemental unit length information (Claim 1).

[0029]

The elemental unit length information may be extracted as an elemental frequency information corresponding to the elemental unit length, a band limiting processing may be effected on the acquired signal based on the extracted elemental frequency information, and thereafter the ratio of the information length of the binary digit information may be read (Claim 2). Further, the periodic signal may be generated so as to be synchronism with the acquired signal and have an elemental frequency

corresponding to the elemental unit length, and this periodic signal may be extracted as the elemental unit length information (Claim 3).

[0030]

According to the present invention, there is proposed a method of reading information including a step of acquiring a value from a signal containing binary digit information having a predetermined information length and deriving from information elements arrayed one-dimensionally on a medium at every equal time interval, wherein when an elemental unit length of the information length of the binary digit information is extracted from the acquired signal, the portion of the signal for extracting the state of the binary digit information from the medium information has a band narrower than that of the characteristic for differentiation based on the equal time interval Claim 4).

[0031]

According to the present invention, there is provided a read signal processing unit characterized by including means for making extraction from a signal which is acquired from a medium, has a predetermined information length, and contains binary digit information deriving from information elements arrayed one-dimensionally on the medium, an elemental frequency corresponding to the elemental unit length of the information length of the binary digit information from the acquired signal; and means for effecting a band limiting processing on the acquired signal based on the extracted elemental frequency signal and thereafter extracting boundary information of said binary digit

information (Claim 5).

[0032]

According to the present invention, there is provided an information reading apparatus characterized by including a signal acquiring unit for acquiring from a medium, a signal containing binary digit information having a predetermined information length and an arrangement, an elemental frequency extracting unit for extracting an elemental frequency corresponding to an elemental unit length of the binary digit information of the information length from the acquired signal, a band limiting unit for limiting a frequency band of the acquired signal based on the extracted elemental frequency information, a timing point extracting unit for extracting a timing point which is in synchronism with the acquired signal and has the elemental frequency, based on the acquired signal and the elemental frequency information, an amplitude extracting unit for extracting an amplitude value of a signal from the band limiting unit in accordance with the timing point extracted by the timing point extracting unit, a tri-state value generating unit for generating tri-state value data from the amplitude values extracted by the amplitude extracting unit in accordance with the timing point, and a reading unit for reading a ratio of the binary digit information to the information length by calculating the tri-state value data generated by the tri-state value generating unit (Claim 6).

[0033]

According to the present invention, there is provided an

information reading apparatus for reading information from a medium having a mark representing a data group composed of a predetermined number of pairs of information elements, each of the information elements being composed of a white region and a black region disposed alternately with a certain width arranged to have an association with coded data, the information reading apparatus acquiring the data group information as an integer number ratio between the data widths of each information element pair, the information reading apparatus including a signal acquiring unit for detecting an analog signal having a variation corresponding to an intensity variation of a reflected ray of light which is caused by scanning the mark on the medium with a ray of light running at a predetermined velocity in the scanning direction, and effecting a sampling operation on the continuous signal at a predetermined sampling frequency to acquire the data group information represented by the mark recorded on the medium in a form of digital signal, an elemental frequency extracting unit for extracting an elemental frequency corresponding to an elemental unit length of the width of the white region and the black region from the acquired signal in the form of digital signal, a band limiting unit for limiting a frequency band of the acquired signal based on the extracted elemental frequency information, a timing point extracting unit for extracting a timing point which is in synchronism with the acquired signal and has the elemental frequency, based on the acquired signal and the elemental frequency information, an amplitude extracting unit for extracting an amplitude value of a signal from the band

limiting unit in accordance with the timing point extracted by the timing point extracting unit, a tri-state value generating unit for generating tri-state value data from the amplitude values extracted by the amplitude extracting unit in accordance with the timing point, and a reading unit for reading a ratio of the binary digit information to the information length by calculating the tri-state value data generated by the tri-state value generating unit, wherein relationship among a width, bar[μ m] of the white region or the black region representing the elemental unit length of the binary digit information, the scanning velocity, vmax[m/s] of the scanning ray of light, and the sampling frequency, fs[MHz] can be expressed by the following equation

$$2 < \frac{fs}{(2 * bar / vmax)} \leq 10 \text{ (Claim 7).}$$

[0034]

According to the present invention, there is proposed a method of acquiring a signal for use with an information reading apparatus having a signal acquiring unit for acquiring a signal containing binary digit information recorded on a medium so as to have a predetermined information length, the information reading apparatus being arranged to extract information regarding an elemental unit length of the information length of the binary digit information from the acquired signal, thereby to read a ratio of the binary digit information to the information length based on the extracted elemental unit length information, the method of acquiring a signal for use with the information reading apparatus characterized in that the signal acquiring

unit acquires a signal containing the signal component and also a component other than one deriving from the medium having the binary digit information recorded thereon, determination is made on the acquired signal so as to identify a signal portion deriving from the medium having the binary digit information recorded thereon by using an amplitude averaging calculation processing, and the signal component deriving from the medium is cut out in accordance with the result of determination, and the cut-out portion is acquired as a signal containing the binary digit information. With this arrangement, the portion of the signal containing no binary digit information can be excluded from a target of acquisition (Claim 8).

[0035]

According to the present invention, there is proposed a method of effecting a band limiting processing for use with an information reading apparatus characterized in that, as a preprocessing for reading the ratio data of the binary digit information to the information length, an elemental frequency corresponding to the elemental unit length is extracted from the acquired signal, and the frequency band of the acquired signal is limited based on the extracted elemental frequency (Claim 9).

Further, according to the present invention, there is proposed a method of extracting a timing point amplitude for use with an information reading apparatus characterized in that, as a preprocessing for reading the ratio data of the binary digit information to the information length, a timing point in

synchronism with the acquired signal and having the elemental frequency is extracted based on the acquired signal and the elemental frequency information, an amplitude value of a signal from the band limiting unit is extracted in accordance with the extracted timing point, and tri-state value data is generated from the extracted amplitude values in accordance with the timing point (Claim 10).

[0036]

[Mode for Carrying out the Invention]

Embodiments of the present invention will be hereinafter described with reference to drawings.

(A-1) Explanation of Overall Construction of Bar Code Reading Apparatus to Which One Embodiment of the Present Invention is Applied

Initially, an overall construction of a bar code reading apparatus according to the present embodiment will be described.

[0037]

FIG. 1 is a block diagram showing the overall construction of the bar code reading apparatus according to one embodiment of the present invention. The bar code reading apparatus shown in FIG. 1 also has an outward appearance similar to that shown in FIG. 57. The bar code reading apparatus can read a bar code as a mark recorded on a medium. Also, the bar code reading apparatus is arranged to include an optical scanning section 1A, an analog processing unit 1B, an AD converter 1d and a reading processing section 1C.

[0038]

In other words, the bar code reading apparatus of the present embodiment is arranged to acquire a signal containing binary digit information (width-length data represented by white regions and black regions constituting the bar code) disposed on the medium so as to have a predetermined information length. Further, the bar code reading apparatus is arranged to extract information concerning an elemental unit length (module) of the information length of the binary digit information from the acquired signal, and read a ratio of information length of the binary digit information (bar code information) based on the extracted elemental unit length information.

[0039]

The optical scanning section 1A is arranged to include an LD1a-1 emitting a light beam and a polygon mirror 1a-2 composed of a mirror face body reflecting the light beam from the LD1a-1. The polygon mirror 1a-2 is rotated by a rotating driving force given by a motor, although not shown. The polygon mirror can provide a plural kinds of scanning patterns by varying the orientation of the reflected light beam. If the polygon mirror is employed in a bar code reader having a system shown in FIG. 57, the polygon mirror is provided near the inside of a reading window face 53a.

[0040]

The light beam emitted from the LD1a-1 is led to the outside (of the housing) through the reading window 53a owing to the rotation of the polygon mirror 1a-2. On the outside of the reading window 53a, a bar code 1 is held so that the bar code

can be irradiated with the aforesaid light beam, whereby respective black bars or white bars of the bar code can be scanned by the light beam shifting in a direction from the left end to the right end thereof, for example.

[0041]

An analog processing section 1B is composed of a light receiving unit 1b and an amplifying unit 1c. The light receiving unit 1b receives a ray of light containing the reflected light beam irradiated on the aforesaid bar code 1 and entering from the outside through the reading window 53a. The light receiving unit also converts the ray of light into an electric signal in a photoelectric manner so that the amplitude value thereof corresponds to the intensity variation of the ray of light. The amplifying unit 1c is a unit for effecting a necessary amplifying processing on the photoelectric converted signal supplied from the light receiving unit 1b.

[0042]

The AD converter 1d is a unit for carrying out digital sampling on the photoelectric converted signal as an analog signal supplied from the amplifying unit 1c and outputting the resultant signal as a digital signal. The present embodiment may have a variation in which the AD converter 1d is obviated and an analog filter is provided so as to effect a band limiting differentiation processing to be effected at the downstream stage of the reading processing unit.

The optical scanning section 1A, the analog processing section 1B and the AD converter 1d are substantially similar

to those shown in FIG. 59 (see references 103A, 103B, 103d).

[0043]

The optical scanning section 1A, the analog processing section 1B, the AD converter 1d and a cut-out unit 1e function as a signal acquiring unit for acquiring a signal containing binary digit information having a predetermined information length deriving from the bar code disposed on the medium.

The reading processing section 1C is arranged to include the cut-out unit 1e, an adaptive-type band limiting differentiating unit 1f, an every module point amplitude extracting unit 1i, a module number calculating unit 1m and a character arrangement checking unit 1n.

The cut-out unit 1e is a unit for extracting from the photoelectric converted signal, a signal which is presumably one deriving from the bar code, in order to reduce a load imposed on the processing to be effected in the downstream stage. That is, as will be described later on, the cut-out unit 1e examines each portion of a signal inputted thereto from the aforesaid AD converter 1d and determines whether the portion of the signal is a portion of the photoelectric converted signal deriving from the lay of light reflected on the bar code. If it is determined that the portion of the photoelectric converted signal is one deriving from the lay of light reflected on the bar code, this portion is cut out and acquired for respective steps of signal processing carried out in the downstream stage.

[0044]

The adaptive-type band limiting differentiating unit 1f

is arranged to include a module frequency extracting unit 1g for extracting a frequency corresponding to an elemental module of the bar code signal, a band limiting differentiation processing unit 1h for limiting a frequency band of a signal supplied from the cut-out unit 1e based on the frequency extracted by the module frequency extracting unit 1g, and a decimation processing unit 1h' for effecting decimation to reduce the data amount of a signal supplied from the band limiting differentiation processing unit 1h. The arrangement of the adaptive-type band limiting differentiating unit 1f will be described in detail later on.

[0045]

The module frequency extracting unit 1g has a function as an elemental frequency extracting unit for extracting an elemental frequency corresponding to an elemental unit length of the information length of the binary digit information from the acquired signal. The band limiting differentiation processing unit 1h has a function as a band limiting unit for limiting the frequency band of the acquired signal based on the extracted elemental frequency information. The every module point amplitude extracting unit 1i is arranged to include a module timing signal extracting unit 1j for extracting a timing signal of the module in accordance with a frequency corresponding to the elemental module extracted by the aforesaid adaptive-type band limiting differentiating unit 1f, an amplitude extracting unit 1k for extracting an amplitude value of a differentiated signal by using the timing signal, and a tri-state value

generating unit 11 for forming the amplitude value extracted by the amplitude extracting unit 1i into an edge signal composed of tri-state data which can take any of three values of "+1", "0" and "-1".

[0046]

The aforesaid timing signal extracting unit 1j has a function as a timing point extracting unit for extracting a timing point synchronized with the acquired signal and having the elemental frequency, based on the acquired signal and the elemental frequency information which are supplied from the adaptive-type frequency band limiting differentiating unit 1f. The amplitude extracting unit 1k has a function for extracting an amplitude value from a signal supplied from the band limiting unit (the adaptive-type frequency band limiting differentiating unit 1f) in accordance with the timing point extracted by the timing point extracting unit. The tri-state value generating unit 11 has a function as a tri-state value generating unit for leading an amplitude value as the tri-state data in accordance with the timing point extracted by the amplitude extracting unit.

[0047]

The module number calculating unit 1m is a unit for reading the bar code information expressed as a width length of respective bars constituting the bar code based on the tri-state data supplied from the every module point amplitude extracting unit 1i.

The character arrangement checking unit 1n is a unit for demodulating a bar code character of the data arrangement pattern

of the bar code information read by the aforesaid module calculating unit 1m with reference to the bar code standard.

[0048]

As described above, according to the bar code reading apparatus of the present embodiment, the mark (bar code) is composed of white regions and black regions as information elements with width length data, and the white regions and the black regions are alternately disposed to represent a data group having a predetermined set of information elements, and the bar code reading apparatus acquires information from the bar code attached on a medium by reading the data group information as an integer number ratio between each pair of width length data.

[0049]

Then, the optical scanning section 1A makes a ray of light scan the upper surface of the bar code at a predetermined speed, the analog processing section 1B receives a reflected ray of light deriving from the scanned ray of light reflected on the mark and detects intensity variation information corresponding to the scanning in the aforesaid direction as a signal, whereby the analog processing section acquires a signal containing binary digit information corresponding the intensity variation of the reflected ray of light.

Further, the module frequency extracting unit 1g extracts the elemental frequency corresponding to the elemental width time of the width length data from the acquired signal, the band limiting differentiating unit 1h limits the signal band of the acquired signal so that the acquired signal has an optimum signal

band, based on the extracted elemental frequency, and the every module point amplitude extracting unit 1i, the module number calculating unit 1m and the character arrangement checking unit 1n reads the integer number ratio between each pair of width length data from the acquired signal having undergone the band limitation, based on the elemental frequency.

[0050]

In more concretely, the optical scanning section 1A generates a plural patterns of laser scanning patterns. When one of the generated patterns scans the bar code, that is, the laser beam scans the bar code, the luminous energy variation of the reflected ray of light from the bar code 1 is collected and the light receiving unit 1b converts the luminous energy into an electric signal.

The bar code reflects the ray of light with different amount of luminous energy depending on which of the white bar and the black bar the reflection is brought about. Therefore, the reflected ray of light comes to have a luminous energy variation depending on the white portion and the black portion. The luminous energy variation is subjected to a proper amplifying processing in the light receiving element amplifier 1c made up of pin photodiodes or the like. Thereafter, the resulting signal is subjected to a sampling process in the AD converter 1d (to carry out analog-to-digital conversion).

[0051]

The cut-out unit 1e extracts from the output series from the AD converter 1d, a signal portion (see signal 1p) having

a feature presumably deriving from the bar code 1. The cut-out unit prevents the rest of the signal portions from being supplied to the next stage. Thus, the processing blocks of the downstream stage can be relieved from a lot of processing load.

The adaptive-type band limiting differentiating unit 1f removes undesirable noise components from the signal portion 1p which is cut out by the cut-out unit 1e so as to have the feature presumably deriving from the bar code. Thus, the signal portion is subjected to the band limiting processing so that the signal portion has an optimum signal band and secures only a component necessary for extracting the module.

[0052]

In order to realize the above arrangement, initially, the module frequency extracting unit 1g extracts a frequency component corresponding to one module (elemental module) of the bar code (see signal 1r) from the input signal 1p. In response to the result 1r thereof, a filter serving as the band limiting differentiation processing unit 1h is provided and this input signal 1p is inputted into the filter 1h. The band limited differentiation signal is reliably given information necessary for extracting the module and has been limited to have the narrowest band. Therefore, this signal has the smallest noise level.

[0053]

In other words, the filter serving as the band limiting differentiation processing unit 1h is arranged in accordance with the frequency extracted by the module frequency extracting

unit 1g. This filter removes high frequency noise causing deterioration in the width information extracting accuracy, and also this filter allows only a minimum band necessary for extracting the width information to pass therethrough.

A signal passing through the filter 1h is subjected to a decimation processing for carrying out decimation to reduce the amount of data. The resulting signal is supplied to the every module point amplitude extracting unit 1i as a signal 1q.

[0054]

The module timing signal extracting unit 1j extracts a timing signal 1s corresponding to a module from the signal 1q which has been subjected to the band limiting processing in the adaptive-type band limiting differentiation unit 1f. In accordance with the timing signal 1s, an amplitude value of the signal 1q is extracted (see signal 1t). Since the signal 1t generates information indicative of whether or not an edge point is present at every module timing, it becomes unnecessary to count a bar width by using an excessively high rate clock. Also, it becomes unnecessary to calculate the ratio of the module.

[0055]

In other words, the every module point amplitude extracting unit 1i finds a point 1s corresponding to a timing of the module from the signal 1q which has passed through the adaptive-type band limiting differentiating unit 1f. In accordance with the timing, an amplitude value of the differentiated signal 1q having undergone the band limiting operation is extracted and the amplitude value is supplied to the subsequent tri-state value

generating unit 11 (signal 1t). At this time, deviation between the real module timing point and the module timing point determined by the sampling is detected and this deviation is corrected, whereby the timing accuracy is secured.

[0056]

The tri-state value generating unit 11 generates a series of tri-state values composed of any of "+1", "0", "-1" based on the aforesaid signal 1t, and supplies the resultant signal to the subsequent module number calculating unit 1m (see signal 1u). At this time, if the scanner is a type in which laser beam is utilized for the scanning, decrease in resolution due to the Gaussian beam (intersymbol interference) is corrected.

Further, when the tri-state value generating unit 11 carries out tri-state value allocation to the amplitude value of every module timing point, automatic equalizing processing is effected based on the least-squares method. When a laser beam is employed for reading a bar code held in a reading area remote from the apparatus, the beam diameter will be expanded. But owing to the automatic equalizing processing based on the least-squares method, the intersymbol interference can be prevented from being brought about.

[0057]

The module number calculating unit 1m calculates the bar code information as a module pattern expressed by the white-black level bar code, based on the aforesaid tri-state value data, and outputs the result of calculation to the character arrangement checking unit 1n (see signal 1v). The character

arrangement checking unit l_n examines the calculated module pattern with reference to the bar code standard. Thus, the bar code character can be demodulated (lw).

[0058]

As described above, according to the bar code reading apparatus of the present embodiment, the adaptive-type band limiting differentiating unit l_f limits the frequency band of the acquired signal. Therefore, the subsequent every module point amplitude extracting unit l_i and the module number calculating unit l_m can carry out signal processing for reading the information length ratio of the binary digit information from the acquired signal in an optimum band. Accordingly, the receiving side circuit need not handle a wide area of frequency band, the signal to noise ratio (S/N) can be improved, a reading area thereof can be expanded, and reading resolution can be also improved. Moreover, if the medium itself contains a cause of reading noise, the reading accuracy is also improved.

[0059]

Further, when the elemental unit length of the information length of the binary digit information is measured, it becomes unnecessary to prepare a high rate clock. Thus, even if the sampling accuracy is set to not very high level, the level of accuracy in reading the binary digit information can be kept high. Therefore, even a clock driving at a relatively low rate can manage the generation of the sampling frequency. Accordingly, the cost of hardware for constructing the apparatus arrangement can be remarkably decreased.

[0060]

Furthermore, according to the present embodiment, it is possible to extract from the acquired signal, the module frequency corresponding to the module length time in the bar width length data, limit the signal band of the acquired signal so as to make the acquired signal have an optimum signal band based on the extracted module frequency, and read the integer number ratio between respective bar width length data from the acquired signal having undergone the band limitation based on the module frequency. Therefore, the receiving side circuit need not handle a wide area of frequency band, the signal to noise ratio (S/N) can be improved, with the result that advantage similar to those of the above case can be obtained.

[0061]

(A-2) Description of Transversal Filter Employed in Main Portion of Present Embodiment

FIG. 3 is a block diagram showing a transversal filter employed in a main portion of the present embodiment. A transversal filter is a digital filter in which tap coefficients are set to obtain a filter characteristic. This transversal filter is arranged to include delaying units 2a-1 to 2a-8, multipliers 2b-1 to 2b-9, a total sum arithmetic operator 2c, and a tap coefficient holding unit 2d for holding therein nine tap coefficients.

[0062]

When sampling is effected on an analog waveform such as one shown in FIG. 2 to obtain finite set of digital data X_0 ,

..., and this finite set of digital data is subjected to the transversal filter, then an output signal y_0, \dots , of which coefficient values are dependent of the following equation (1) can be obtained.

$$y_n = \sum C_i x_{n-i} \quad \dots(1)$$

The transversal filter employed in the main portion of the bar code reading apparatus according to the present embodiment is arranged to have a necessary number of steps for obtaining a desired characteristic.

[0063]

(A-3) Band Limitation for Signal to be Processed by Reading Processing Unit

According to the present embodiment, the bar code reading apparatus acquires a signal containing the binary digit information having a predetermined information length deriving from a ray of light reflected on information elements which are arrayed in a one-dimensional manner on the medium (signal for detecting the intensity variation of a ray of light reflected on the bar code). Information regarding the elemental unit length (bar code module length) of the information length of the binary digit information is extracted from the acquired signal 1_p , and a ratio of the information length of the binary digit information (bar code information) is extracted based on the extracted elemental unit length information.

[0064]

FIGS. 4(a) to 4(d) are diagrams each for explaining a band limiting characteristic for the signal in the reading processing

section 1C of the present embodiment.

As for example shown in FIG. 4(c), if the reading processing section is supplied with an input signal (x) composed of sequential digits of "0", "0", "1", "0", "0" having a rectangular pattern (see a solid line waveform in the diagram), this signal can be differentiated by using a differentiating circuit including a delaying unit 4a and an adding unit 4b shown in FIG. 4(a). Thus, the signal will be converted into a signal composed of sequential digits of "0", "1", "-1", "0" (output signal (y); see a dot line waveform in the same diagram). In this way, it becomes possible to extract an edge at which the input signal changes its status from "0" to "1" or an edge at which the input signal changes its status from "1" to "0".

[0065]

The differentiating circuit shown in FIG. 4(a) employs a time interval of differentiation which is equivalent to the elemental module of the bar code ($T=1$ module). If the differentiating processing is effected at an interval shorter than that interval, the response waveform will become sharp as shown in FIG. 4(b) while if the differentiating processing is effected at an interval longer than that interval, the response waveform will become blunt as shown in FIG. 4(d).

[0066]

As a manner of band processing effected in the reading processing section 1C of the present embodiment, it is recommendable for the time interval to be set to one corresponding to the elemental module of the bar code so as to attain an optimum

signal processing. However, if the signal processing is effected at the time interval set to one shorter than the elemental module, an excessive noise sensitivity can be caused in the reading processing section. Conversely, if the signal processing is effected at the time interval set to one longer than that time interval, then as shown in FIG. 4(d), an intersymbol interference is brought about due to the input pattern, leading to a waveform distortion, with the result that it becomes difficult to find an expected edge.

[0067]

Accordingly, as for the band limiting characteristic of the reading processing section 1C of the present embodiment, arrangement is made to provide a differential processing characteristic of a time interval to respective steps of processing stemming from one at which the intensity variation detecting signal is acquired from the aforesaid reflected ray of light to one at which the integer number ratio between each pair of width length data pieces can be read. That is, the respective steps of processing come to have a differential processing characteristic of a time interval which is substantially equivalent to a time (elemental width time) corresponding to the elemental unit length (module length) or a time interval slightly smaller than that time interval.

[0068]

As described above, according to the present embodiment, information regarding the module length of the information length of the bar code information is extracted from the acquired signal,

and the bar code information can be read based on the extracted module length information. Therefore, it becomes possible to suppress the size of hardware and a price thereof and to improve the S/N ratio of the reading signal and reading resolution. Moreover, even if the depth of field for reading is enlarged or a concave/convex portion or a blurred portion is left on the reading face, reading precision can be improved.

[0069]

(B-1) Description of Cut-out Unit of Bar Code Reading Apparatus According to Present Embodiment

Subsequently, an arrangement of the cut-out unit 1e of the bar code reading apparatus according to the present embodiment will be hereinafter described with reference to FIGS. 5 to 7.

FIG. 5 is a block diagram showing in detail the cut-out unit 1e of the bar code reading apparatus according to the present embodiment. As shown in FIG. 5, the cut-out unit 1e is arranged to include a feature extracting unit 30a, a determining unit 30b and a gate 30h.

[0070]

The feature extracting unit 30a is a unit for extracting a feature of the photoelectric converted signal of the digital signal supplied from the AD converter 1d. This unit is arranged to include a wide band differentiation processing unit 30c, a squaring processing unit 30d and a moving average calculating unit 30e.

The wide band differentiation processing unit 30c is a

unit for effecting wide band differentiation processing on a photoelectric converted signal of the digital signal supplied from the AD converter 1d so as to remove noise therefrom. The squaring processing unit 30d is a unit for carrying out squaring calculation processing at every sampling data on the photoelectric converted signal having undergone the wide band differentiation processing in order to facilitate the subsequent operation of comparing amplitude values with each other. The moving average unit 30e is a unit for calculating moving average on the digital signal having undergone the squaring calculating processing in the squaring processing unit 30d.

[0071]

For example, the AD converter 1d converts an analog waveform (x) such as one shown in FIG. 6(a) into a digital signal, and this digital signal is supplied to the wide band differentiation processing unit 30c in which the digital signal is subjected to the wide band differentiation processing. Thus, a digital signal corresponding to an analog waveform shown in FIG. 6(b) is obtained. Further, this signal is subjected to the squaring calculation processing in the squaring processing unit 30d, and thereafter the moving average unit 30e calculates a moving average of 300 taps, for example. Thus, a digital signal corresponding to an analog waveform (y) shown in FIG. 6(c) can be obtained.

[0072]

Further, the determining unit 30b has a threshold value holding unit 30f and a comparing unit 30g. When the determining

unit is supplied with a result of moving average calculated by the aforesaid feature extracting unit 30a, the comparing unit 30g compares the value as the result of calculation with a predetermined threshold value held in the threshold value holding unit 30f. In this way, it is determined whether the supplied photoelectric converted signal is a signal deriving from the ray of light reflected on the bar code or not.

[0073]

In more concretely, the comparing unit 30g examines whether or not the value is larger than the predetermined threshold value. If it is determined that the value exceeds the threshold value, then a signal falling in a section in which the moving average calculation is effected is a bar code signal. On the other hand, if the value does not exceed the threshold value, then it is determined that the signal is any other signal than the bar code signal. That is, since the squaring processing unit 30d squares the amplitude data, the value of the signal having undergone the moving average processing will be enlarged, with the result that it becomes easier to determine whether the signal derives from the ray of light reflected on the bar code or not based on the magnitude of the amplitude value.

[0074]

In other words, the above-described feature extracting unit 30a and the determining unit 30b function as a determining unit for determining whether or not the electric signal supplied from the light receiving unit 1b is created by converting a ray of light reflected on the bar code as a medium into the electric

signal.

The gate unit 30h is supplied with a signal of the result of comparing determination from the comparing unit 30g. If it is determined that the input signal is an electric signal deriving from the conversion on the ray of light reflected on the bar code, then a component of the input signal is acquired in order for the subsequent signal processing. Conversely, if it is determined that the input signal is an electric signal deriving from the conversion on any other ray of light than one reflected on the bar code, then the component of the input signal is excluded from a target to be acquired for the subsequent signal processing.

[0075]

Meanwhile, the aforesaid threshold value holding unit 30f may be arranged to hold a half value ($y(\text{half})$) of a value ($y(\text{max})$) acquired as the maximum value of the moving-averaged value as a threshold value. When the aforesaid comparing unit 30g and the gate unit 30h carries out the cut-out processing on the input signal, as for example shown in FIG. 7, the cut-out section may be set to data (t_1 to t_2) corresponding to twice the time period in which the moving-averaged value exceeds the threshold value.

[0076]

With the above arrangement, when a signal is acquired, the cut-out unit 1e is supplied with a bar code signal containing a signal other than one deriving from the medium (bar code) having binary digit information recorded thereon. The feature extracting unit 30a and the determining unit 30b effects the amplitude averaging calculation processing on a portion of the

signal taken out of the input signal which derives from the medium having the binary digit information recorded thereon. Thus, determination is carried out. The gate unit 30h cuts out the portion of the signal from the bar code in accordance with the result of determination provided by the determining unit 30b. Then, the cut-out portion is acquired as a signal containing the binary digit information.

[0077]

As described above, according to the present embodiment, the feature extracting unit 30a and the determining unit 30b can examine whether or not the electric signal supplied from the photoelectric converting unit 1b derives from conversion on a ray of light reflected on the medium into the electric signal, and the gate unit 30h responds to the result of determination in such a manner that a signal component determined as one deriving from conversion on the reflected ray of light is acquired as an acquired signal while a signal component determined as one deriving from conversion on any other ray of light than the reflected ray of light is excluded from a target to be acquired as an acquired signal. Accordingly, a signal portion other than one necessary for acquiring the binary digit information can be excluded from a target of subsequent signal processing in the information reading apparatus, and hence the processing load imposed on the apparatus can be decreased.

[0078]

Furthermore, according to the present invention, when the signal acquiring section and units 1B, 1d and 1e acquire a signal

from the medium having the bar code information recorded thereon, these section and units are supplied with a signal containing a signal component other than one deriving from the medium. Of the signals supplied thereto, a portion of the signal deriving from the medium having the bar code information recorded thereon is subjected to the amplitude averaging calculation processing to carry out determination. Then, the portion of the signal deriving from the medium is cut out in accordance with the result of determination, and the cut-out portion is acquired as a signal containing the binary digit information. Accordingly, a signal portion other than one necessary for acquiring the binary digit information can be excluded from a target of subsequent signal processing in the information reading apparatus, and hence the processing load imposed on the apparatus can be decreased.

[0079]

(B-2) Description of Cut-out Unit of Bar Code Reading Apparatus as Modification of Present Embodiment

In addition to the arrangement shown in FIG. 5, the above-described cut-out unit 1e can be implemented by an arrangement shown in FIG. 8. That is, the cut-out unit 1e shown in FIG. 8 is arranged to include a feature extracting unit 31a, a determining unit 31b and a gate 31n. However, the main portions thereof are different from each other.

[0080]

The feature extracting unit 31a is arranged to include a differentiation processing unit 31c, a squaring processing unit 31d, a moving average unit 31e, a first threshold value

holding unit 31f, a first comparing unit 31g and a gate unit 31h. Each of the differentiation processing unit 31c, the squaring processing unit 31d, the moving average unit 31e, the first threshold value holding unit 31f, and the first comparing unit 31g has a function similar to that of corresponding one of components (see references 30c to 30g) in FIG. 5.

[0081]

The gate unit 31h is a unit for carrying out cut-out processing on a signal squared by the squared processing unit 31d (squared signal) based on the result of comparison supplied from the first comparing unit 31g.

In more concretely, if the comparing unit 31g determines that the input signal is one deriving from conversion into the electric signal on a ray of light reflected on the bar code, the squaring processing unit 31d carries out cut-out processing on the differentiated squared signal corresponding to the signal component to supply to the determining unit 31b. Conversely, if the comparing unit 31g determines that the input signal is one deriving from conversion into an electric signal on the electric signal of a ray of light other than one reflected on the bar code, the squaring processing unit 31d excludes the differentiating squared signal corresponding to the signal component from a target of acquisition for the signal processing in the determining unit 31b.

[0082]

The determining unit 31b is arranged to receive a signal supplied from the above-described feature extracting unit 31a

and determines whether or not the electric signal from the light receiving unit 1b is one deriving from conversion on a ray of light reflected on the bar code. This determination can be made at an accuracy of noise signal removal higher than that of the determination in the arrangement shown in FIG. 7. The determining unit is arranged to include a mean value calculating unit 31i, a maximum value extracting unit 31j, a division processing unit 31k, a second threshold value holding unit 31l, and a second comparing unit 31m.

[0083]

The mean value calculating unit 31i is a unit for calculating a mean value of the differentiated squared signal falling in a section cut out by the gate unit 31h of the feature extracting unit 31a. The maximum value extracting unit 31j is a unit for extracting the maximum value of the differentiated squared signal falling in the above-described cut-out section. The division processing unit 31k is a unit for dividing the maximum value supplied from the aforesaid maximum value extracting unit 31j by a mean value supplied from the mean value calculating unit 31i.

[0084]

The second comparing unit 31m is a unit for examining whether or not the result of arithmetic operation from the division processing unit 31k stays under a threshold value held in the second threshold value holding unit 31l. If the result of arithmetic operation stays under the threshold value, then it is determined that the signal falling in the section is one

deriving from conversion into an electric signal on a ray of light reflected on the bar code. Conversely, if the result of arithmetic operation does not stay under the threshold value, then it is determined that the signal falling in the section is an electric signal deriving from conversion on a ray of light other than one reflected on the bar code.

[0085]

In other words, the aforesaid gate unit 31h carries out examination on a value deriving from dividing the maximum value of the signal falling in the cut-out section by the mean value. Then, the difference between the maximum value and the mean value is examined. If it is determined that the difference is smaller than the threshold value, then the signal is regarded as a bar code signal and cut out. That is, the signal of the bar code portion has a nature that an amplitude variation is relatively even as compared with other noise portions. Therefore, if the difference between the maximum value and the mean value is relatively small as compared with those of signals of other sections, then the signal can be regarded as a bar code signal.

[0086]

Similarly to the corresponding component (one identified by reference 30h) in FIG. 5, the gate unit 31n responds to the result of comparing determination supplied from the second comparing unit 31m in such a manner that if the input signal is one deriving from the conversion into the electric signal on the ray of light reflected on the bar code, then the component of the signal falling in the section is acquired for the subsequent

signal processing, and if the input signal is one deriving from the conversion into the electric signal on one other than the ray of light reflected on the bar code, then the component of the signal falling in the section is excluded from a target of acquisition for the subsequent signal processing.

[0087]

When the above-described arrangement examines the ray of light received by the light receiving unit 1b to determine whether the ray of light is one scanning the bar code (mark) by the optical scanning section 1A, the following steps are carried out. That is, the wide band differentiation processing unit 31c effects differentiation processing on the optical signal containing a variation of intensity thereof, the squaring processing unit 31d squares the differentiated signal supplied from the wide band differentiation processing unit 31c, and thereafter the moving average unit 31e calculates a moving average on the differentiated squared signal supplied from the squaring unit 31d.

[0088]

The first comparing unit 31g examines whether the calculated moving average value exceeds a predetermined first threshold value or not. The gate unit 31h responds to the result of determination supplied from the first comparing unit 31g in such a manner that if it is determined that the moving average value exceeds the first threshold value, then the differentiated squared signal is validated while if it is determined that the moving average value does not exceed the first threshold value,

then the differentiated squared signal is invalidated.

[0089]

The mean value calculating unit 31i is supplied from the gate unit 31h with the differentiated squared signal falling in the effective period, and calculates a mean value of the differentiated squared signal. The maximum value extracting unit 31j extracts the maximum value of the differentiated squared signal falling in the effective period supplied from the gate unit 31h.

The dividing unit 31k divides the maximum value extracted by the aforesaid maximum value extracting unit 31j by the mean value calculated by the mean value calculating unit 31i, so that calculation is made to determine difference between the mean value and the maximum value of the differentiated squared signal falling in the validated period.

[0090]

The second comparing unit 31m compares a divided value representing the difference between the mean value and the maximum value calculated by the dividing unit 31k with a second threshold value held in the second threshold value holding unit 31l, and outputs the result of comparing determination to the gate unit 31n.

The gate unit 31n responds to the result of comparing determination supplied from the second comparing unit 31m in such a manner that if the divide value is smaller than the second threshold value, then a part of the intensity variation state detecting signal is cut out at the corresponding period and only

the cut-out portion of the signal is acquired to feed it to the subsequent adaptive-type band limiting differentiating unit 1f while if the divide value is larger than the second threshold value, then the part of the intensity variation state detecting signal at the corresponding period is excluded from a target to be acquired.

[0091]

For example, the AD converter 1d converts an analog waveform (x) such as one shown in FIG. 9(a) into a digital signal, and this digital signal is supplied to the wide band differentiation processing unit 31c and the squaring processing unit 31d in which the digital signal is subjected to corresponding steps of processing, respectively. Thus, a digital signal corresponding to an analog waveform shown in FIG. 9(b) is obtained. Further, this signal is subjected to the following processing. That is, a part of the signal falling in a section is cut out by the gate unit 31h and the maximum value is determined in the part of the signal falling in the section. Then, the maximum value is divided by a mean value calculated as shown in FIG. 9(c). In this way, it becomes possible to obtain a divided value representing the difference between the maximum value and the mean value.

[0092]

In this case, of the differentiated squared signal portions in sections 31-2a to 31-2c cut out by the gate unit 31h, if the second comparing unit 31m determines that the divided value stays under the threshold value only in the section 31-2a of the signal

portion shown in FIG. 9(b), then the signal of the section 31-2a (see reference 31-1a of FIG. 9(a)) is acquired as the bar code signal, and outputted to the subsequent stage (in more concretely, the adaptive-type band limiting differentiation processing unit 1f).

[0093]

In FIG. 9(b), as for the bar code signal portion of the differentiated squared signal falling in the section 31-2a and noise portions of the same falling in the sections 31-2b and 31-2c, the maximum values are "0.009384", "0.009380", and "0.008213", respectively, and the mean values of the same are "0.00163", "0.000548", and "0.000455", respectively. Thus, the results of division in the division processing unit 31k are "5.757", "17.12" and "18.05", respectively.

[0094]

In this case, the second comparing unit 31m may be set to have a comparing reference "10" as the second threshold value. With this setting, if the result of division made by the division processing unit 31k is equal to or smaller than "10" as in the case of section 31-2a, then the signal falling in the section can be regarded as a bar code signal. Conversely, if the result of division made by the division processing unit 31k is larger than "10" as in the case of sections 31-2b and 31-2c, then the signal falling in the sections can be regarded as not the bar code signal.

[0095]

Accordingly, also in this case, the feature extracting

unit 31a and the determining unit 31b can examine whether or not the electric signal supplied from the light receiving unit 1b is one deriving from conversion into the electric signal on the ray of light reflected on the medium. And the gate unit 31n responds to the result of examination in such a manner that a signal component determined as one deriving from conversion on the reflected ray of light into the electric signal is acquired as an acquired signal while a signal component determined as one deriving from conversion into the electric signal on any other ray of light than the reflected ray of light is excluded from a target to be acquired as an acquired signal. Accordingly, a signal portion other than one necessary for acquiring the binary digit information can be excluded from the target of subsequent signal processing in the information reading apparatus, and hence the processing load imposed on the apparatus can be decreased. In addition, the noise removal can be carried out at an accuracy higher than in the case of aforesaid FIG. 5. Therefore, load of signal processing imposed on the subsequent stage can be decreased.

[0096]

According to the arrangement of the bar code reading apparatus of the present embodiment, the AD converter is provided, an electric signal supplied from the light receiving unit 1b is subjected to conversion from an analog signal to a digital signal and resulting signal is supplied to the feature extracting unit 30a and the determining unit 30b. Then, it is examined whether or not the electric signal is one deriving from conversion

into the electric signal on a ray of light reflected on the bar code based on the digital signal supplied from the AD converter 1d. However, according to the present invention, arrangement can be made in such a manner that the AD converter is obviated and a circuit is provided so that an analog signal supplied from the analog processing section 1B can be subjected to the cut-out processing in a manner similar to one in the above-described case by using an analog signal.

[0097]

(C) Detailed Description on Adaptive-Type Band Limiting Differentiating Unit of Bar Code Reading Apparatus According to Present Embodiment

The adaptive-type band limiting differentiating unit 1f of the bar code reading apparatus according to the present embodiment will be hereinafter described in detail.

(C-1) Description of Main Portion of Adaptive-type Band Limiting Differentiating Processing According to Present Embodiment

Initially, a main portion of the signal processing carried out in the adaptive-type band limited differentiating unit 1f will hereinafter be described with reference to FIGS. 10 and 11.

[0098]

The bar code to be read by using the bar code reading apparatus shown in FIG. 1 can be obtained by creating a printed pattern 6b composed of white and black elements as shown in FIG. 10 based on the module information (binary digit information

having a predetermined information length composed of information elements arrayed one-dimensionally) 6a.

When the bar code reading apparatus reads the bar code arranged as described above, a laser beam (Gaussian beam) 6c is scanned on the bar code to make the scanning light beam be reflected thereon. The reflected light beam is collected by the light receiving unit 1b of the bar code reading apparatus in which the reflected light beam is converted in a photoelectric manner. The photoelectric converted signal is amplified by the amplifying unit 1c up to a level suitable for processing in the subsequent stage (see reference 6d in FIG. 10 and FIGS. 11(a) to 11(d)).

[0099]

Further, the photoelectric converted signal amplified by the amplifying unit 1c is subjected to an optimum band differentiation processing based on a module frequency f_{mod} (see reference 6e of FIG. 10 and FIG. 11(e)). A module timing is extracted from this signal, and an amplitude value is extracted based on the timing to convert the signal into a series of tri-state values composed of "1", "0" and "-1" (see FIGS. 10 and 11(f)).

[0100]

In other words, on the basis of the acquired signal acquired by the analog processing section 1B, information regarding an elemental unit length (module length) of the information length of the binary digit information is extracted. As the module length information, an elemental frequency (module frequency) corresponding to the module length is extracted. On the basis

of the extracted module frequency information, the acquired signal is subjected to the band limiting processing and thereafter a ratio of the information length of the binary digit information (bar code information) is read.

[0101]

Therefore, as a preprocessing for reading the ratio data of the information length of the binary digit information, an elemental frequency corresponding to the elemental unit length (module length) is extracted from the acquired signal, and the acquired signal is subjected to a process of frequency band limitation based on the extracted elemental frequency.

The characteristic of the optimum band differentiation processing in the above processes may be arranged in such a manner that the gain characteristic thereof is set to a cosine wave equivalent characteristic having a gain peak frequency which corresponds to the elemental width time of the white-black width information of the input signal or a frequency slightly larger than that frequency, and the phase characteristic thereof is set to one linearly variable with respect to the frequency.

[0102]

The band limiting differentiation processing unit 1h carries out a digital filtering processing by using a transversal filter described with reference to FIG. 3. The gain characteristic of the filter is determined in accordance with the following Equations (2) to (4) depending on the module frequency and the phase characteristic thereof is determined in accordance with Equation (5).

In the discussion of Equations (2) to (4), if f_s is set to the sampling frequency of the AD converter l_d , the AD converter l_d is not provided, and the aforesaid band limiting differentiation processing l_h is formed of an analog filter, the following Equation (3) becomes unnecessary.

[0103]

$$\cos((f-f \bmod \pi/(2*f \bmod)) : 0 \leq f \leq 2*f \bmod \dots (2)$$

$$\cos(((f-(f_s-f \bmod))\pi/(2*f \bmod)) : f - 2*f \bmod \leq f \leq f_s \dots (3)$$

$$0 : 2*f \bmod \leq f \leq f_s - 2*f \bmod \dots (4)$$

$$\theta [\text{rad}] = -\pi/f_s * f + \pi/2 (-f_s/2 < f < f_s/2) \dots (5)$$

The characteristic values are determined as follows. That is, f_s is divided equally by n (n is set to any second power number) and resulting numbers are identified by g_0 to g_{n-1} , respectively. When a filter characteristic is identified by the gain characteristic and the phase characteristic, the real part Re and the imaginary part Im are calculated as shown in the following Equations (6) and (7). Then, IFFT (Inverse Fast Fourier Transform) calculation processing is effected on the complex number to determine filter coefficients C_0 to C_{n-1} .

[0104]

$$\text{Re}(n) = g_n * \cos(\theta n) \dots (6)$$

$$\text{Im}(n) = g_n * \sin(\theta n) \dots (7)$$

Then, a convolution filter is arranged so that a coefficient

$C_n/2$ of the obtained coefficients C_0 to C_{n-1} is set to the center of filter taps.

FIGS. 12 to 14 are diagrams showing a gain characteristic, a phase characteristic and a convolution characteristic to which reference is made to examine how these coefficients are determined if a frequency of f_{mod} , or the half of the module frequency is 910kHz. Also, FIGS. 15 to 17 are diagrams showing a gain characteristic, a phase characteristic and a convolution characteristic to which reference is made to examine how these coefficients are determined if f_{mod} is set to 2.5MHz.

[0105]

The photoelectric converted signal amplified by the amplifying unit 1c is converted into a series of discrete values by the AD converter 1d, and the resulting signal is subjected to the filter arithmetic operation (convolution operation) having the above-described characteristic. Then, an output signal comes to have a differentiated waveform as shown in FIG. 18. That is, this waveform becomes such one that when the scanning light beam shifts from a black bar to a white bar, the corresponding signal point takes the maximum value, when the scanning light beam shifts from a white bar to a black bar, the corresponding signal point takes the minimum value, and when the scanning light beam stays in a continuous region of a single black or white bar, the corresponding signal point converges on the zero point.

[0106]

That is, as shown in FIG. 18, if the gain peak frequency

of the filter is coincident with the frequency of half the module frequency of the input signal, the signal becomes optimum in which the edge information is reserved and a high frequency noise components are removed.

If the gain peak frequency of the filter is set to one larger than the frequency of half the module frequency of the input signal, as shown in FIG. 19, the output signal thereof comes to have a differentiated waveform in which the edge information is not deteriorated but a high frequency component is contained.

[0107]

Conversely, if the gain peak frequency of the filter is set to one smaller than the frequency of half the module frequency of the input signal, as shown in FIG. 20, the edge information can be deteriorated due to intersymbol interference of the bar code pattern.

According to the present embodiment, respective steps stemming from one in which the intensity variation signal detecting signal of the reflected ray of light is acquired to one in which the integer number ratio between each width length data pair of the bar code have a differential processing characteristic of a time interval which is substantially equal to a time interval of the elemental width time (time corresponding to the elemental unit length) or a time interval slightly smaller than that time interval. For this reason, the above-described noise component can be prevented from being contained in the signal and the intersymbol interference can be prevented from

being brought about.

[0108]

As for the case of FIG. 12, the differentiating processing can be effected at a band characteristic of 2 MHz which is narrower than the band of the sampling frequency with respect to the acquired signal when the AD converter 1d has a sampling frequency of 10 MHz. Further, as for the case of FIG. 15, the differentiating processing can be effected at a band characteristic of 5 MHz which is narrower than the band of the sampling frequency. On the other hand, if the differentiation processing is carried out in a band of which frequency is equal to or more than the sampling frequency, the waveform comes to have a characteristic that a peak is created at 5 MHz point in FIG. 12 and no aliasing is included. Therefore, it is impossible to obtain a digital filter having a narrow band characteristic which can serve as the aforesaid band limiting differentiation processing unit 1f.

[0109]

Accordingly, when acquisition is made on a signal containing binary digit information having a predetermined information length deriving from data elements arrayed on the medium one-dimensionally as values sampled at every equal time interval by the AD converter 1d, and a module length as the elemental unit length of the information length of the binary digit information is extracted from the acquired signal, the series of steps stemming up to one in which the binary digit information is extracted from the medium information take a band

narrower than the band of the differentiation characteristic for the aforesaid sampling frequency.

[0110]

Further, the module frequency extracting unit 1g extracts the aforesaid module length information as the elemental frequency information (module frequency information) corresponding to the elemental unit length, the band limiting differentiation processing unit 1h effects band limitation and differentiation processing on the read signal based on the extracted elemental frequency information, and thereafter the every module point amplitude extracting unit 1i and the module number calculating unit 1m read the ratio of the information length of the binary digit information.

[0111]

Accordingly, when the elemental unit length of the information length of the binary digit information is extracted from the acquired signal, the signal portion in which the state of the binary digit information is extracted from the medium information can take a band narrower than that of the characteristic for differentiation of the equal time interval. Therefore, when at least the information length of the binary digit information is read, differentiation processing can be carried out for limiting the band to the optimum one.

[0112]

The above explanation of the optimum band differentiation processing of the present embodiment is intended to describe the processes for acquiring an ideal differentiated waveform

from the bar code pattern. Meanwhile, it is needless to say that, with the optimum band differentiation processing, factors such as influence from the Gaussian beam, a distortion characteristic due to a delay of circuit and so on can be removed.

Further, while the above explanation is made on a case in which the scanning is made by a Gaussian beam, the above explanation can be applied to a case in which the bar code pattern is acquired by a CCD (Charge Coupled Device) and the bar code character is demodulated, for example.

[0113]

Furthermore, while the above explanation is made on a case in which the acquired signal is converted into discrete values by the AD converter 1d, the subject technology can be applied to a case in which an analog filter is introduced. Moreover, in the above description, the phase is set to one varying linearly, the way of varying the phase is not limited to the case, but the characteristic thereof may be set to one in which a phase shift of about 90 degrees may be introduced in the range of $f=0$ to $fs/2$, for example.

(C-2) Description of Main Portion of Optimum Band Differentiation Processing in Modification of Present Embodiment

In the above case of (A-4), the optimum band differentiation processing effected by the band limiting differentiation processing unit 1h is implemented by a filtering processing by a filter having a gain characteristic of a cosine characteristic, the gain characteristic of the filter is not

limited to the above one. That is, the filter may be arranged to have a characteristic approximated to the aforesaid cosine characteristic or a squared cosine characteristic expressed by the following Equations (8) to (10), for example, and the differentiation processing can be carried out by such a filter in a manner similar to that described above.

[0114]

$$\cos^2((f-f \bmod) \pi / (2*f \bmod)) : 0 \leq f \leq 2*f \bmod$$

... (8)

$$\cos^2(((f-(fs-f \bmod)) \pi / (2*f \bmod)) : fs-2*f \bmod \leq f \leq fs$$

... (9)

$$0 : 2*f \bmod \leq f \leq fs - 2*f \bmod$$

... (10)

That is, the characteristic of the filter for carrying out the aforesaid optimum band differentiation processing is such one that the gain characteristic thereof is set to a squared cosine wave of which cosine function is equivalent to characteristic having a gain peak frequency corresponding to the elemental width time of the white-black width information of the input signal or a frequency slightly larger than that frequency, and the phase characteristic thereof is set to one linearly variable with respect to the frequency.

[0115]

Also in the discussion of Equations (8) to (10), f_s represents the sampling frequency of the AD converter 1d. Therefore, if the AD converter 1d is not provided and the aforesaid band limiting differentiation processing 1h is formed of an

analog filter, then condition expressed by the above Equation (9) becomes unnecessary.

Description will be made for reference on a case in which the aforesaid filter characteristic is arranged so that the gain characteristic is set to a cosine characteristic and the phase characteristic takes 0 [rad] throughout the whole range of the frequency.

[0116]

In this case, the module frequency is necessary to be set to the center frequency. FIG. 21 shows a resulting waveform of the signal having undergone the filter. As will be understood from the waveform, the edge information of the bar code signal resides in each zero-cross point (e.g., a point A or B in the figure).

Accordingly, if a circuit having the aforesaid filter characteristic is employed, the subsequent processing (e.g., a processing in the every module point amplitude extracting unit 11) can employ a conventional system for extracting the zero-cross point in order to extract the bar code module number. Also in this case, the gain characteristic may be set not to the cosine characteristic but to a squared cosine characteristic.

[0117]

(C-3) Description of Adaptive-Type Band Limiting Differentiating Unit of Bar Code Reading Apparatus According to Present Embodiment

FIG. 22 is a block diagram showing the adaptive-type band limiting differentiating unit of the bar code reading apparatus

according to the present embodiment. As shown in FIG. 22, the adaptive-type band limiting differentiating unit if is arranged to have the module frequency extracting unit 1g, the band limiting differentiation processing unit 1h and a decimation processing unit 1h'.

[0118]

The module frequency extracting unit (elemental frequency extracting unit) 1g can be more fully broken down into components of a wide band differentiation processing unit 11a, a squaring processing unit 11b, an FFT processing unit 11c and a spectrum peak frequency extracting unit 11d and 1/2 calculating unit 11e. The module frequency extracting unit serves as a unit for extracting the module frequency information as the elemental frequency from the photoelectric converted signal (digital signal) which is cut out by the cut-out unit 1e.

[0119]

The wide band differentiation processing unit 11a is a unit for effecting wide band differentiation processing on the photoelectric converted signal (digital signal) cut out by the cut-out unit 1e. In more concretely, the wide band differentiation processing unit carries out a filter processing with a filter having a characteristic in which a value larger than the maximum frequency of the acquire signal in a readable region is set to a gain peak frequency, in a manner described above in detail in (C-1).

[0120]

The squaring unit 11b is a unit for squaring the signal

having undergone the differentiation processing in the wide band differentiation processing unit 11a. The FFT processing unit 11c is a unit for effecting an FFT (Fast Fourier Transform) processing on the differentiated squared signal squared in the squaring processing unit 11b. The spectrum peak frequency extracting unit 11d is a unit for extracting information regarding the peak frequency from the frequency spectrum obtained as a result of the aforesaid FFT processing.

Furthermore, the 1/2 calculating unit 11e is a unit which carries out calculation to determine the half peak frequency extracted by the spectrum peak frequency extracting unit 11d and outputs the half peak frequency as the above-described module frequency.

[0121]

That is, of the signals seemingly a bar code signal cut-out by the cut-out unit 1e, the highest frequency of the signal as the frequency spectrum except for the direct current level is the twice the module frequency. This is because the differentiated signal is second-powered and hence the module frequency component thereof comes to have twice the frequency band. Accordingly, the peak frequency extracted by the spectrum peak frequency extracting unit 11d is subjected to calculation to determine the half thereof in the 1/2 calculating unit 11e, with the result that the obtained frequency can be regarded as the module frequency.

[0122]

For example, if the aforesaid FFT processing unit 11c carries out the FFT processing to obtain a spectrum such as one

shown in FIG. 23, then the spectrum peak frequency extracting unit 11d extracts a frequency of a spectrum peak 11-2a. Thereafter, the 1/2 calculating unit 11e carries out calculation to determine the half frequency of the spectrum peak 11-2a extracted in the above manner and supplies the half frequency of the spectrum peak to the convolution processing unit 11g as a gain peak frequency for the differentiation processing.

[0123]

The band limiting differentiation processing unit (band limiting unit) 1h is arranged to have a 1/2 calculating unit 11e, a filter coefficient calculating unit 11f, and a convolution processing unit 11g. The band limiting differentiation processing unit is a unit for carrying out differentiation processing for limiting a band of the photoelectric converted signal (digital signal) cut out by the cut-out unit 1e based on the module frequency information extracted by the module frequency extracting unit 1g.

[0124]

Further, the filter coefficient calculating unit 1f determines convolution coefficients of the differentiating filter for the band limitation based on the frequency f_{mod} which is the half module frequency information calculated by the aforesaid 1/2 calculating unit 11e, in accordance with the aforesaid scheme of (C-1). That is, the aforesaid Equations (2) to (5) are calculated by using the frequency f_{mod} , or the half module frequency, to obtain the gain characteristic and the phase characteristic of the filter, and then the convolution

coefficients (filter coefficients) of the filter are determined by way of the FFT calculation based on the gain characteristic and the phase characteristic thereof.

[0125]

The convolution processing unit 11g is a unit for constructing a digital filter such as an FIR (Finite Impulse Response) filter by using the convolution filter coefficients calculated by the filter coefficient calculating unit 11f, and thereby effecting differentiation processing on the photoelectric converted signal (digital signal) in the optimized band supplied from the cut-out unit 1e.

The decimation processing unit 1h' is supplied with a signal (digital signal) having undergone the convolution processing in the convolution processing unit 11g and effects decimation on the digital signal so that number of data pieces are decimated depending on the aforesaid module frequency. The arrangement thereof will be more fully described later on.

[0126]

With the above arrangement, when the module frequency (elemental frequency) is extracted by the module frequency extracting unit 1g of the adaptive-type band limiting differentiating unit 1f, the photoelectric converted signal (acquired signal) acquired by the cut-out unit 1e is subjected to the wide band differentiation processing unit 11a in which differentiation processing is effected so that the gain peak frequency is set to a value equal to or larger than the maximum frequency of the acquired signal in the readable region.

[0127]

The squaring processing unit 11b effects squaring processing on the signal having undergone the differentiation processing in the wide band differentiation processing unit. The FFT processing unit carries out frequency spectrum analysis on the result having undergone the squaring processing. The spectrum peak frequency extracting unit 11d selects a significant frequency except for 0Hz from the result of analysis based on the frequency spectrum and generates the frequency as the module frequency.

[0128]

The band limiting differentiation processing unit 1h carries out filter arrangement by using the module frequency extracted in the above-described manner in such a manner that the gain characteristic is set to a cosine equivalent characteristic in which the gain peak frequency thereof is substantially a frequency corresponding to the half module frequency or a frequency slightly larger than the substantial half module frequency and the phase characteristic is set to one varying linearly with respect to the frequency. Further, the band limiting differentiation processing unit effects the convolution processing. In this way, it becomes possible to obtain a differentiated waveform of which band is optimized.

[0129]

According to the present invention, information concerning the module length of the bar width length of the bar code information can be extracted from the acquired signal, and

the ratio of the information length of the binary digit information can be read based on the extracted module length information. Therefore, it becomes possible to suppress a size of hardware and a price thereof and to improve the S/N ratio of the reading signal and reading resolution. Moreover, even if the depth of field for reading is enlarged or a concave/convex portion or a blurred portion is left on the reading face, reading precision can be improved.

[0130]

Furthermore, the module frequency corresponding to the module length can be extracted and the frequency band of the acquired signal can be limited based on the extracted module frequency. Therefore, information concerning the elemental unit length of the information length of the binary digit can be extracted from the acquired signal, and on the basis of the extracted elemental unit length information, the ratio of the information length of the binary digit information can be read. Accordingly, advantages similar to those of the above-described one can be obtained.

[0131]

(C-4) Description of Adaptive-Type Band Limiting
Differentiating Unit of Bar Code Reading Apparatus According
to Modification of Present Embodiment

FIG. 24 is a block diagram showing an adaptive-type band limiting differentiating unit of the bar code reading apparatus according to one modification of the present embodiment. The adaptive-type band limiting differentiating unit is shown in

FIG. 24 is arranged differently from the aforesaid one shown in FIG. 22. That is, since the FFT processing unit (see reference 11c) extracts frequency information by using a limited number of samples, the frequency information contains error. The subject adaptive-type band limiting differentiating unit is arranged to extract the module frequency in a more precise manner in order for handling the error.

[0132]

The adaptive-type band limiting differentiating unit 1f shown in FIG. 24 includes a module frequency extracting unit 1g having an arrangement different from the aforesaid arrangement shown in FIG. 22. Further, the adaptive-type band limiting differentiating unit is arranged to have the band limiting differentiation processing unit 1h and the decimation processing unit 1h' having fundamentally the same arrangements as those of aforesaid FIG. 22.

The band limiting differentiation processing unit 1h includes a filter coefficient calculating unit 12n and a convolution processing unit 12o (see references 11f and 11g in FIG. 22) similar to those shown in aforesaid FIG. 22.

[0133]

The module frequency extracting unit 1g is arranged to have a first module frequency extracting unit 12f-1 capable of extracting a first module frequency from the photoelectric converted signal (digital signal) acquired by the cut-out unit 1e and a second module frequency extracting unit 12f-2 for extracting a second module frequency based on the first module

frequency.

[0134]

The first module frequency extracting unit 12f-1 is arranged to have a wide band differentiation processing unit 12a, a squaring processing unit 12b, an FFT processing unit 12c and a spectrum peak frequency extracting unit 12d corresponding to the aforesaid function components shown in FIG. 22 (see references 11a to 11e). Therefore, the first module frequency extracted by the first module frequency extracting unit 12f-1 is a module frequency extracted by a processing similar to that effected by the aforesaid module frequency extracting unit 1f shown in FIG. 22.

[0135]

Further, the second module frequency extracting unit 12f-2 is arranged to have multiplying units 12h-1 and 12h-2, an LPF (Low Pass Filter) 12h-3, 12h-4, an amplitude normalizing unit 12i, a vector difference calculating unit 12j, a phase calculating unit 12k, an integrating unit 12l, a module f2 extracting unit 12m.

The multiplying unit 12h-1 is a unit for multiplying the differentiated squared signal (X_n) supplied from the squaring processing unit 12b and a cosine function, $\cos(2\pi f_1)$ of the first module frequency f_1 obtained by the first module frequency extracting unit 12f-1 together. The multiplying unit 12h-2 is a unit for multiplying the differentiated squared signal (X_n) supplied from the squaring processing unit 12b and a sine function, $-\sin(2\pi f_1)$ of the first module frequency f_1 obtained by the

first module frequency extracting unit 12f-1 together.

[0136]

Therefore, owing to the multiplying units 12h-1 and 12h-2, the module frequency f1 is applied to the differentiated squared signal to form a vector as expressed by the following Equations (11) and (12). In the following Equations (11) and (12), n represents a number sequentially attached to each sampled data based on a chronological sequence beginning with "1", and ts represents a sampling period thereof.

$$A_n(\text{Re}) = X_n \cdot \cos(2\pi \cdot f_1 \cdot n \cdot t_s) \quad \cdots(11)$$

$$A_n(\text{Im}) = X_n \cdot (-1) \cdot \sin(2\pi \cdot f_1 \cdot n \cdot t_s) \quad \cdots(12)$$

That is, the relationship between the true module frequency component ($2 \cdot f_0$) having no error and the module frequency f1 extracted by the first module frequency extracting unit 12f-1 can be expressed by the following Equation (13) owing to the aforesaid vector formation.

[0137]

$$\Delta f = 2 \cdot f_0 - f_1 \quad \cdots(13)$$

The LPFs 12h-3 and 12h-4 are composed of an FIR filter or the like and arranged to extract only the aforesaid Δf component. The amplitude normalizing unit 12i is a unit for normalizing the amplitudes of vector signals 12p and 12q passing through the aforesaid LPFs 12h-3 and 12h-4 in accordance with the following Equations (14) and (15).

[0138]

$$B_n(\text{Re}) = 1 / \sqrt{(A_n(\text{Re})^2 + A_n(\text{Im})^2)} \cdot A_n(\text{Re}) \quad \cdots(14)$$

$$B_n(\text{Im}) = 1 / \sqrt{(A_n(\text{Re})^2 + A_n(\text{Im})^2)} \cdot A_n(\text{Im}) \quad \cdots(15)$$

The vector difference calculating unit 12j is a unit for calculating an opponent of the complex number pair of complex number data 12r which has been normalized by the amplitude normalizing unit 12i and delayed by one sample time amount as expressed by Equation (16), thereby determining a vector difference. The vector difference calculating unit is arranged to have a delaying unit 12j-1 for delaying the complex data 12r by one sample time amount and multiplier 12j-2. In the following Equation (16), references B and C represent vectors. However, vector expression is not introduced for convenience of notation. Further, (*) designates an opponent of the complex number pair.

[0139]

$$C_n = B_n * B_n - 1(*) \quad \cdots(16)$$

The phase calculating unit 12k is a unit for calculating respective phases of vector data series 12t as a result of calculation on the vector difference supplied from the vector difference calculating unit 12j. The integrating unit 12l is a unit for integrating the phase difference data calculated by the phase calculating unit 12k. This integrating operation is effected at the unit of cut-out action of the cut-out unit 1e, whereby calculation is made on a phase variation amount θ_{sum} .

[0140]

That is, the phase of the vector calculated in difference by the vector difference calculating unit 12j is based on the frequency error of the first module frequency. Therefore, if integration is made on the phase difference data, the phase variation amount θ_{sum} can be calculated at the unit of time

sectioned by the cut-out unit 1e.

Further, the module f2 extracting unit 12m is a unit for calculating the module frequency error Δf based on the phase variation amount θ_{sum} within a unit of cut-out section (t) supplied from the integrating unit 12l in accordance with the following Equations (17) and (18) and utilizing the error amount to correct the first module frequency f1 into an accurate second module frequency f2.

[0141]

$$\Delta f = \theta_{sum}/(2\pi t) \quad \cdots(17)$$

$$f2 = f1 + \Delta f \quad \cdots(18)$$

With the above arrangement, the first module frequency extracting unit 12f-1 of the adaptive-type band limiting differentiating unit 1f shown in FIG. 24 effects a differentiation processing upon extracting the module frequency information (elemental frequency information) in such a manner that the wide band differentiation processing unit 12a effects the differentiation processing on the acquired signal supplied from the cut-out unit 1e so that the gain peak frequency is set to a value equal to or more than the maximum frequency of the acquired signal falling in a readable region.

[0142]

Further, the squaring processing unit 12b effects squaring processing on the signal having undergone the differentiation processing. The FFT processing unit 12c carries out frequency spectrum analysis on the signal resulting from the squaring processing. The spectrum peak frequency extracting unit 12d

extracts a significant frequency except for 0Hz from the result of frequency spectrum analysis, determines the frequency as an already calculated elemental frequency corresponding to the elemental unit length, and supplies the frequency information as the first module frequency.

[0143]

On the basis of the frequency obtained by the already calculated frequency supplied from the first module frequency extracting unit 12f-1, the second module frequency extracting unit 12f-2 effects demodulation processing on the signal having undergone the squaring processing in the squaring processing unit 12b. Further, the multiplying units 12h-1 and 12h-2 vectorize the signal, and the LPFs 12h-3 and 12h-4 remove a high frequency component from the demodulated and vectorized signal.

[0144]

Further, the vector difference calculating unit 12j calculates a phase difference between the signal from which the high frequency component is removed by the LPFs 12h-3 and 12h-4 and a signal having undergone delaying process by one sample time amount. Thereafter, the phase calculating unit 12k and the integrating unit 12l calculates the frequency deviation Δf between the aforesaid first module frequency and the accurate module frequency based on the phase difference obtained by the vector difference calculating unit 12j. The module frequency f_2 extracting unit 12m determines a result from addition of the calculated Δf and the aforesaid first module frequency f_1 together as an error-corrected second module frequency.

[0145]

For example, if the first module frequency f1 is determined as 454101Hz, the output signal 12p from the LPF 12h-3 comes to have a waveform 12-1a shown in FIG. 25 while if the output signal 12q from the LPF 12h-4 comes to have a waveform 12-1b shown in FIG. 25. The phase variation in the cut-out period calculated by the integrating unit 12l becomes as shown in FIG. 26.

[0146]

In the case of FIG. 26, at the cut-out start timing point (signal acquisition start timing point for the cut-out unit 1e; $t = 0[\mu s]$), the phase thereof takes a value of "-0.76[rad]" while at the cut-out completion timing point ($t = 2047[\mu s]$), the phase thereof takes a value of "1.18[rad]".

In this way, the integrating unit 12l calculates the phase variation θ_{sum} in the unit cut-out section based on Equation (19) to yield "2.94[rad]". Further, the module f2 extracting unit 12m obtains a value of "229[Hz]" for the error amount frequency Δf as in the following Equation (20) (see Equation (17)). Also, the unit obtains a value of "454230[Hz]" for the corrected accurate module frequency f2 as in the following Equation (21) (see Equation (18)).

[0147]

$$\theta_{sum} = (1.18) - (-0.76) = 2.94[\text{rad}] \quad \cdots(19)$$

$$\begin{aligned} \Delta f &= 2.94\text{rad}/(2\pi*2047\mu\text{s}) \\ &= 229\text{Hz} \end{aligned} \quad \cdots(20)$$

$$\begin{aligned} f2 &= f1 + \Delta f \\ &= 454101\text{Hz} + 229\text{Hz} \end{aligned}$$

= 454330Hz

…(21)

As described above, when the module frequency f2 having undergone the correcting process for correcting the frequency error is extracted, similarly to the aforesaid case of (C-3), the filter coefficient calculating unit 12n of the band sine differentiation processing unit 1h determines the convolution coefficients of the differentiating filter. The convolution processing unit 12o carries out the convolution processing on the signal supplied from the cut-out unit 1e by using the coefficients. Thus, a differentiated waveform of which band is optimized can be obtained.

[0148]

Accordingly, also in this case, information concerning the module length of the bar width length of the bar code information can be extracted from the acquired signal, and the bar code information can be read based on the extracted module length information. Therefore, it becomes possible to suppress the size of hardware and a price thereof and to improve the S/N ratio of the reading signal and reading resolution. Moreover, even if the depth of field for reading is enlarged or a concave/convex portion or a blurred portion is left on the reading face, reading precision can be improved.

[0149]

(C-5) Description of Decimation Processing after Adaptive-Type Band Limiting Differentiation Processing in Present Embodiment

The decimation processing unit 1h' of the adaptive-type

band limiting differentiation processing unit 1f will be hereinafter described in detail.

FIGS. 27 and 28 are diagrams for explaining the processing carried out in the decimation processing unit 1h' of the aforesaid adaptive-type band limiting differentiation processing unit 1f. The decimation processing unit 1h' is composed of a digital filter or the like such as one shown in FIG. 3, for example. The decimation processing unit is supplied with a signal (digital signal) having undergone band limiting processing in the band limiting differentiation processing unit 1h, and decimates data piece number from the digital signal depending on the aforesaid module frequency. Thus, the amount of calculation task imposed on the subsequent stage can be reduced.

[0150]

In other words, when a signal containing binary digit information is acquired, the signal is acquired as a digital signal deriving from a sampling process effected at a predetermined sampling interval. On the other hand, as a preprocessing for reading bar code information as an integer number ratio between width length data pair, the decimation processing unit 1h' can decimate the data number from the digital signal having undergone the signal band limitation process depending on the module frequency information.

[0151]

That is, as shown in flowchart of FIG. 27, at step S1, the aforesaid module frequency extracting unit 1g extracts the module frequency, and it is examined which of the sections ①

to ④ shown in FIG. 28 the extracted module frequency falls in (step S2). Then, the decimation is effected on the signal having undergone the band limitation in the band limiting differentiation processing unit 1h to reduce the data amount thereof, and the resulting signal is supplied to the subsequent every module point amplitude extracting unit 1i.

[0152]

The processing effected in the decimation processing unit 1h' will be described more concretely. That is, if the extracted module frequency falls in a region between a point of 625[kHz] to a point of 1.25[MHz] (see the region ② in FIG. 28), then decimation is effected on the signal from the band limiting differentiation processing unit 1h to reduce the data amount thereof to 1/2 (step S3 of FIG. 27).

In a similar manner, if the module frequency falls in a region between a point of 312.5[kHz] to the point of 625[kHz] (see the region ③ in FIG. 28), then decimation is effected on the signal to reduce the data amount thereof to 1/4 (step S4). And if the module frequency falls in a region between a point of 166.25[kHz] to the point of 312.5[kHz] (see the region ④ in FIG. 28), then decimation is effected on the signal to reduce the data amount thereof to 1/8 (step S5).

[0153]

If the module frequency extracted by the module frequency extracting unit 1g supplied to the decimation processing unit 1h' ranges from 1.25[MHz] to 2.5[MHz] (see region ① of FIG. 28), the decimation for reducing the data amount is not carried

out and the module frequency is directly supplied to the subsequent every module point amplitude extracting unit 11 (step S2).

Accordingly, owing to the function of the decimation processing unit 1h', when the signal containing the bar code information is acquired, the signal can be acquired as a digital signal deriving from the sampling at the predetermined sampling frequency, and as a preprocessing for reading the integer ratio between each bar width length data pair, the digital signal having undergone the signal band limitation can be subjected to the data number decimation depending on the module frequency information. Therefore, the bar code information can be read without requiring a large number of sampling point of the signal depending on the decrease of the module frequency. That is, the signal can be subjected to the data decimation process for reducing the optimum data amount depending on the module frequency number, with the result that the amount of calculation task can be decreased.

[0154]

(D) Description of Every Module Point Amplitude Extracting Unit of Bar Code Reading Apparatus According to Present Embodiment

Description will be hereinafter made on an every module point amplitude extracting unit of the bar code reading apparatus according to the present embodiment.

(D-1) Description of Overall Arrangement of Every Module Point Amplitude Extracting Unit of Bar Code Reading Apparatus

According to Present Embodiment

FIG. 29 is a block diagram showing an arrangement of an every module point amplitude extracting unit 1i. As shown in FIG. 29, the every module point amplitude extracting unit 1i is arranged to have a module timing signal extracting unit 1j, an amplitude extracting unit 1k and a tri-state value generating unit 1l. The every module point amplitude extracting unit is a unit arranged for generating a periodic signal which is in synchronism with the acquired signal and has an elemental frequency corresponding to the module length. Thus, module information can be extracted.

[0155]

The module timing signal extracting unit 1j is further arranged to have a tone signal generating filter 14a, a Hilbert transform unit 14b, a phase calculating unit 14c, a zero-radian point timing extracting unit 14d and a delay time calculating unit 14e.

The tone signal generating filter 14a is a unit for generating a timing signal as a tone signal (periodic signal) based on the acquired signal (photoelectric converted signal) having undergone band limitation in the aforesaid adaptive-type band limiting differentiating unit 1f and the extracted module frequency. This timing signal can be generated as a tone signal with a sine-wave-like waveform having a frequency corresponding to the unit module width of the bar code. The detail thereof will be described in (D-2).

[0156]

The Hilbert transform unit 14b is a unit for effecting Hilbert transform on the tone signal supplied from the tone signal generating filter 14a. In this Hilbert transform unit, the tone signal from the tone signal generating filter 14a is set to a real part (Re) of the complex number and a signal having undergone the Hilbert transform processing is set to an imaginary part (Im) of the complex number, and the resulting complex number is supplied to the subsequent phase calculating unit 14c, whereby a signal of each sample point can be formed into a vector.

[0157]

Further, the phase calculating unit 14c is a unit for calculating a phase of the sample point formed into a vector as described above. The zero-radian point timing extracting unit 14d is a unit for extracting a point at which the phase becomes zero-point based on the phase information calculated by the phase calculating unit 14c and deriving the module timing. The delay time calculating unit 14e is a unit for calculating, at every deriving module timing, the delay time of the sample point with respect to the point at which the phase extracted by the zero-radian timing extracting unit 14d becomes a zero-point.

[0158]

Meanwhile, the amplitude extracting unit 1k is further arranged to have a delay filter 14f and an amplitude extracting unit 14g. The delay filter 14f serves as a delay filter based on the delay time calculated by the aforesaid delay time calculating unit 14e. The delay filter effects a delay

processing on the acquired signal supplied from the adaptive-type bandlimiting differentiating unit 1f by a convolution processing. With this filtering operation, the sample point can be made coincident with the zero-radian timing point.

[0159]

The tri-state value generating unit 11 is further arranged to have an LMS (Least Mean Square) 14h as an automatic equalizing unit and a wave error determining unit 14i. The LMS 14h is a unit for automatically equalizing the amplitude data (see reference 14q in FIG. 29) extracted at every module timing, thereby generating tri-state data composed of "1", "0" and "-1". The wave error determining unit 14i is a unit for examining the amplitude data formed into the tri-state data by the LMS 14h so as to determine whether there is error contained or not.

[0160]

With the above arrangement, the every module point amplitude extracting unit 1i shown in FIG. 29 carries out the following steps as a preprocessing for reading the ratio (bar code information) of the information length of the binary digit information on the basis of the acquired signal having undergone the band limiting processing in the adaptive-type band limiting differentiating unit 1f and the module frequency information. That is, the every module point amplitude extracting unit extracts a timing point in synchronism with the acquired signal and having the module frequency, extracts an amplitude value of the signal supplied from the adaptive-type band limiting differentiating unit 1f in accordance with the extracted timing

point, and leads the amplitude value in accordance with the extracted timing point as tri-state value data.

[0161]

In otherwords, the every module point amplitude extracting unit li extracts the timing point at which module length data resides from the acquired signal. The subsequent module number calculating unit lm reads the integer ratio between each width length data pair from the bar code as a mark in accordance with the extracted timing point.

When the timing point is extracted, the every module point amplitude extracting unit li utilizes the acquired signal having undergone the differentiating processing in the adaptive-type band limiting differentiating unit lf as an input signal to extract a frequency component corresponding to the module width time (elemental width time) of the bar code data (width length data), generates a periodic signal corresponding to the elemental width time, and specifies the timing point corresponding to the point at which the bar code width information resides based on the generated periodic signal as an input signal. Meanwhile, the aforesaid adaptive-type band limiting differentiating unit lf may be arranged to have a differentiation characteristic which has been described in the above-described sections of (C-1) or (C-2).

[0162]

For example, if the aforesaid every module point amplitude extracting unit li is supplied with a digital signal having a differentiated waveform 15b shown in FIG. 30 (see sample points

indicated by marks "X" on the waveform 15b) as the acquired signal having undergone the band limitation process, the tone signal generating filter 14a of the module timing signal extracting unit 1j generates a digital signal as a periodic signal corresponding to the tone signal waveform 15c (see sample points indicated by marks "O" on the waveform 15c) on the basis of the aforesaid digital signal 15b and the module frequency information extracted by the module frequency extracting unit 1g. The waveform 15c of the tone signal is synchronize with the waveform 15b of the acquired signal having undergone the band limitation process.

[0163]

The phase calculating unit 14c is supplied with the tone signal generated from the aforesaid tone signal generating filter 14a and a signal deriving from the Hilbert transform effected by the Hilbert transform unit 14b on the tone signal. The phase calculating unit forms a vector based on the supplied signals and calculates phases of respective signal points of the vectored signal. Thus, phase data (digital signal) shown in FIG. 31(a) is generated as the result of calculation.

The zero-radian point timing extracting unit 14d extracts a point at which the phase becomes a zero-radian point based on the phase data calculated by the phase calculating unit 14c. Thus, the module timing can be led. As shown in FIG. 31(a), the phase of the sample point (see FIG. 31(b)) and the actual zero-radian point are different from each other (the sampling is not necessarily effected at the zero-radian point).

Therefore, on the basis of the timing of the zero-radian point extracted by the zero-radian point timing extracting unit 14d, the delay time calculating unit 14e and the delay filter 14f corrects the deviation between the sample point and the zero-radian point.

[0164]

That is, the delay time calculating unit 14e calculates the time difference between the sample point and the zero-radian point for every module timing. The delay filter 14f of the amplitude extracting unit 1k carries out the delay processing. In this way, sample data can be obtained for every module timing. Thereafter, the amplitude extracting unit 14g extracts the differentiated signal amplitude (digital data) as shown in FIG. 31(c).

[0165]

In other words, when the timing point is extracted, the timing point for reading the information length of the binary digit recorded on the bar code is specified based on the differentiated signal of the acquired electric signal, and the digital information composed of tri-state values is extracted from the amplitude of the signal having undergone the differentiation processing at every specified timing point. In order for extracting the above-described digital information composed of the tri-state values, the amplitude value of the signal having undergone the differentiation processing is extracted at every specified timing point and the extracted amplitude value of the signal is converted into digital data

composed of tri-state values.

[0166]

The LMS 14h of the tri-state value generating unit 11 effects automatic equalizing processing on the amplitude value in accordance with the aforesaid timing point extracted by the amplitude extracting unit. Thus, the tri-state value data can be led. The wave error determining unit 14i generates a signal appropriate as a series of bar code reading data.

That is, when the amplitude value extracted at every timing point is converted into the digital signal composed of tri-state values, the tri-state value generating unit 11 determine which of the values "+1", "0" and "-1" the amplitude value of the extracted signal should take and generates the result of determination data composed of tri-state values. Thereafter, the module number calculating unit 1m interprets the data formed into the tri-state values in such a manner that the signal point having data of "+1" located thereat corresponds to a point at which an edge of one of white and black regions resides, the signal point having data of "-1" located thereat corresponds to a point at which an edge of the other of the white and black regions resides, and the signal point having data of "0" located thereat corresponds to a point at which no edge resides. In this way, the integer ratio between each width length data pair of the bar code can be read.

[0167]

Therefore, according to the present embodiment, as a preprocessing for reading the bar width length ratio of the bar

code information, the module timing signal extracting unit 1j extracts the timing point synchronous with the acquired signal and having the elemental frequency based on the acquired signal and the module frequency information, the amplitude extracting unit 1k extracts the amplitude value of the signal supplied from the adaptive-type band limiting differentiating unit 1f in accordance with the extracted timing point, and the amplitude value can be led as the tri-state value data in accordance with the extracted timing point. Therefore, the operation of the information reading can be free from disturbance caused by information deriving from points other than the module timing points, and the resolution in reading information can be improved together with the S/N ratio of the read signal. Furthermore, even if the depth of field for reading is enlarged or a concave/convex portions or a blurred portion are left on the reading face, the reading accuracy can be improved.

[0168]

Moreover, the sampling frequency need not be set to a high frequency in order for measuring the module length of the bar code, and a clock of relatively low price may be sufficient for the sampling operation. Therefore, the cost for constructing the arrangement of the apparatus can be remarkably decreased.

(D-2) Description of Module Timing Signal Extracting Unit of Present Embodiment

Initially, an arrangement of the tone signal generating filter 14a will be described in detail.

[0169]

The above-described tone signal generating filter 14a may be arranged to have a squared cosine characteristic of which gain peak frequency is set to the module frequency extracted by the module frequency extracting unit 1g and a phase characteristic which keeps constant at all.

The description thereof will be provided below.

[0170]

That is, as shown in aforesaid FIG. 30, when the module timing is extracted from the differentiated signal having undergone the band limiting processing, the elemental frequency of the differentiated signal becomes $f\alpha$ because the signal is composed of one white module + one black module (see reference 15d in FIG. 30). On the other hand, the timing frequency becomes $f\beta$ because the signal is composed of unit modules of a white bar or black bar (see reference 15c in FIG. 30).

[0171]

Accordingly, relationship between the module frequency f_1 extracted by the aforesaid module frequency extracting unit 1g and the above-described $f\alpha$ or $f\beta$ can be expressed by the following Equations (22) and (23).

$$f\alpha = f_1 \quad \cdots(22)$$

$$f\beta = f_1 * 2 \quad \cdots(23)$$

That is, the tone signal generating filter is arranged as a filter having a center frequency of $f\beta$. Therefore, if an acquired signal 1q having undergone the band limiting processing is convolution-processed in the tone signal generating filter 14a, a tone signal having this module frequency

component can be led.

[0172]

For example, the characteristics of the tone signal generating filter 14a can be set to those expressed by the following Equations (24) to (26). In Equations (24) to (27), f_s represents a sampling frequency of the AD converter 1d, and fw a band width (-6dB) of the arranged filter.

$$\begin{aligned} \text{gain} &= \cos^2(f - f\beta)\pi / 2 * fw \\ &: (f\beta - fw/2 \leq f < f\beta + fw/2) \end{aligned} \quad \cdots(24)$$

$$\begin{aligned} \text{gain} &= \cos^2((f - (f_s - f\beta)\pi / 2 * fw) \\ &: (f_s - f\beta - fw/2 \leq f < f_s - f\beta + fw/2) \end{aligned} \quad \cdots(25)$$

$\text{gain} = 0$
:(frequency is other one except for a case of Equation
(24) or Equation (25))
...

(26)

$$\text{phase}(\theta [\text{rad}]) = 0 \quad (0 \leq f \leq f_s) \quad \cdots(27)$$

The characteristic of band width represented by fw may be set to one proportional to a reciprocal number of a time length expressing the white-black width information. In more concretely, the band width fw can be calculated by extracting a time length (t_{bar}) representing only the white-black signal (bar code signal) portion from the cut-out signal supplied from the adaptive-type band limiting differentiating unit 1f in accordance with the following Equation (28).

[0173]

$$fw = 1/t_{bar} * k \quad (k \text{ is a fixed value}) \quad \cdots(28)$$

In more concretely, when the central frequency $f\beta$ is set

to 1820kHz, owing to a gain characteristic shown in FIG. 32 and a phase characteristic shown in FIG. 33, the tone signal generating filter 14a can be arranged to be a digital filter having a characteristic shown in FIG. 34. Thus, a signal supplied from the adaptive-type band limiting differentiating unit 1f may be subjected to the convolution processing in the filter 14a to obtain a tone signal.

[0174]

The Hilbert transforming unit 14b and the phase calculating unit 14c will be hereinafter described in detail.

FIG. 35 is a block diagram showing the Hilbert transforming unit 14b and the phase calculating unit 14c of the present embodiment. As shown in FIG. 35, the phase calculating unit 14c is arranged to have a vectoring unit 18a and a calculating unit 18b.

As described above, the Hilbert transforming unit 14b is a unit for effecting Hilbert transform on the tone signal generated by the tone signal generating filter 14a. This Hilbert transforming unit 14b is composed of a digital filter having a characteristic as for example shown in FIG. 36. That is, the Hilbert transforming unit can be arranged to have a transversal filter (see FIG. 3) having a tap shown in FIG. 36.

The vectoring unit 18a of the phase calculating unit 14c is supplied with a signal having a waveform 20a (sample points thereof are indicated by marks "O") shown in FIG. 37, for example, at the real part input port thereof (Re) from the tone signal generating filter 14a and a signal as a result of Hilbert transform

having a waveform 20b (sample points thereof are indicated by marks "X") shown in FIG. 37, for example, at the imaginary part input port thereof (Im) from the Hilbert transforming unit 14b, wherein these signals are vectorized.

[0175]

The calculating unit 18b is a unit for carrying out calculation on the signal vectorized by the vectoring unit 18a based on the following Equation (29) so as to determine the phase of the vectorized signal.

$$\theta = \tan^{-1}(Im/Re) \quad \cdots (29)$$

Subsequently, the arrangement of the zero-radian point timing extracting unit 14d will be described in detail.

[0176]

The zero-radian point timing extracting unit 14d is a unit for extracting a point at which the phase becomes zero radian, on the basis of phase information calculated by the phase calculating unit 14c and shown in FIG. 38(a), for example, so as to derive a module timing.

Since the tone signal generated by the tone signal generating filter 14a has a substantial uniform frequency with a period equivalent to the module frequency, the phase thereof will rotate at a constant rate. As shown in FIGS. 38(a) and 38(b), a point 21d-1 at which the phase of the tone signal becomes zero-radian has the same timing as that of the module point 21d-2 of the differentiated signal. In this way, this zero-radian point is extracted and the zero-radian point is utilized as timing information for extracting the amplitude value of the

differentiated signal 21g at every timing.

[0177]

At this event, of the sample points, a point closest to the zero-radian is extracted and this point is utilized as a timing. For example, of the couple of sample points 21a and 21b neighboring the zero-radian point 21d-1 shown in FIG. 38(a), the sample point 21a is closer than the other to the zero-radian point and hence this point is determined as the aforesaid module timing.

[0178]

Further, the delay time calculating unit 14e is a unit for calculating the time difference of the module timing determined by the aforesaid zero-radian point timing extracting unit 14d with respect to the actual zero-radian point. The delay time calculating unit outputs the time difference as a delay time difference td .

With the above arrangement, according to the module timing signal extracting unit 1j of the present embodiment, the tone signal generating filter 14a is supplied with a signal having undergone the signal differentiation processing and generates a periodic signal corresponding to the elemental width time (module length time) of the width length data.

[0179]

Subsequently, when examination is made to specify a timing point serving as a point at which the width information resides, the phase calculating unit 14c calculates a phase of tone signal as the periodic signal generated by the tone signal generating

filter 14a. When the phase of the aforesaid periodic signal is calculated, this periodic signal is vectorized and calculation is made for determining the phase of the aforesaid periodic signal. In more concretely, when the aforesaid periodic signal is vectorized, the periodic signal from the tone signal generating filter 14a is set to the real part of the complex while the signal deriving from the periodic signal from the tone signal generating filter 14a and having undergone the Hilbert transform in the Hilbert transforming unit 14b is set to the imaginary part of the same.

[0180]

The zero-radian point timing extracting unit 14d receives the result of calculation from the phase calculating unit 14c, extracts time information (timing information) of a point at which the phase of the tone signal as a periodic signal becomes zero degree, and specifies the extracted time information as a timing point. Further, the aforesaid zero-radian point extracting unit 14d responds to the result of the phase calculation from the phase calculating unit 14c in such a manner that, of a pair of signal points adjacent to each other and having signs opposite to each other, a point closer than the other to the zero-degree point is specified as the aforesaid timing point.

[0181]

The delay time calculating unit 14e extracts the time error between the timing point specified by the zero-radian point timing extracting unit 14d and the point at which the tone signal generated by the tone signal generating filter 14a comes to have

a phase of zero degree. The delay filter 14f of the amplitude extracting unit 1k provides an amount of delay corresponding to the aforesaid time error to the differentiated signal from the adaptive-type band limiting differentiating unit 1f at every timing point at which the time error is extracted.

[0182]

(D-3) Description of Amplitude Extracting Unit of Present Embodiment

As more fully shown in FIG. 39, the delay filter 14f of the amplitude extracting unit 1k is arranged to have a tap coefficient memorizing unit 22a, a first-order equation approximating unit 22b, a 1/2 decimating unit 22c and a convolution processing unit 22d.

The tap coefficient memorizing unit 22a is a unit for holding filter coefficients (X_0 to X_{2n-1}) making it possible for the subsequent convolution processing unit 22d to carry out a filter processing which allows the photoelectric converted signal to pass through the filter satisfactorily and has a low-pass characteristic with twice the accuracy of the sampling frequency. The first-order equation approximating unit 22b introduces the delay time td supplied from the aforesaid delay time calculating unit 14e for interpolating the low-pass filter coefficients (X_0 to X_{2n-1}) by using a first-order equation approximation in a manner expressed by the following Equation (30).

[0183]

$$Y_m = (X_{m+1} - X_m)td/(ts/2) + X_m \quad (m=0 \text{ to } 2n-1) \quad \cdots (30)$$

As shown in FIG. 40, an y-axis is set in to indicate the filter coefficient value and an x-axis is set in to indicate time, and of the filter coefficient values X_0 to X_{2n-1} , a couple of filter coefficients adjacent to each other are selected so that the couple of filter coefficients lie on a first-order equation. In this assumption, the time distance between X_{m+1} to X_m corresponds to half the sampling interval t_s of the AD converter 1d. Thus, the difference between X_{m+1} to X_m can be utilized to determine the aforesaid first-order equation.

[0184]

Therefore, a value delayed by the delay time t_d relative to the filter coefficient X_m can be led as expressed by the aforesaid Equation (30). In this way, each of the filter coefficient values held in the filter coefficient holding unit 21a can be determined so that these filter coefficient can construct a filter having a delaying characteristic of the delay time t_d calculated by the delay time calculating unit 14e.

[0185]

The 1/2 decimating unit 22c decimates the filter coefficients after undergoing the delay processing at a rate of 1/2, whereby the filter coefficients of the sampling frequency, which was set to twice that of the AD converter 1d to improve accuracy thereof, is made equivalent to that of the photoelectric converted signal.

For example, if the filter coefficients are not subjected to the delaying process, the sample points thereof will be plotted on points of mark "X" lying on a waveform 24a of FIG. 41.

Conversely, if the filter coefficients are subjected to the processing of the aforesaid first-order equation approximating unit 22b and the 1/2 decimating unit 22c, the sample points thereof will be corrected so as to lie on the points of mark "○" on a waveform 24b of FIG. 41. Points of mark "◇" represent a set of filter coefficients having an ideal delay characteristic. The above-described processing of the first-order equation approximating unit 22b and the 1/2 decimating unit 22c is effected at every module timing.

[0186]

The convolution processing unit 22d is composed of a digital filter such as a transversal filter having an aforesaid system shown in FIG. 3, for example. The convolution processing unit effects a convolution processing on the differentiated signal 1q having undergone the band limiting processing supplied from the adaptive-type band limiting differentiating unit 1f by using the filter coefficients provided by the 1/2 decimating unit 22c.

As described above, the amplitude extracting unit 14g is supplied from the delay filter 14f with a signal containing information of the sample point extracted at the true module timing, and the amplitude extracting unit extracts the amplitude value at the sample point. Thus, the amplitude information can be outputted at the true module timing to the subsequent tri-state value generating unit 11.

[0187]

In the above arrangement of the delay filter 14f shown

in FIG. 39, convolutional filtering processing can be carried out in such a manner that the gain thereof is set to one until the signal falls within the maximum input signal band in which the signal is allowed to be read as the intensity variation detecting signal, the gain thereof is gradually attenuated as the band thereof is remote from the maximum input signal band, and the signal is delayed in accordance with the amount of time error calculated by the delay time calculating unit 14e. In this way, the signal can undergo the differentiating processing effected at every timing point at which the time error is calculated, and this signal having undergone the differentiating processing can be delayed by an amount corresponding to the aforesaid time error.

[0188]

In the above-described delay filter 14f, when the coefficients for the filter processing are determined, impulse response data is calculated based on a filter characteristic function in which the gain thereof is set to one until the signal falls within the maximum input signal band allowing the signal to be read as the intensity variation detecting signal and the gain thereof is gradually attenuated as the band thereof is remote from the maximum input signal band. Then, in the first-order equation approximating unit 22b, the aforesaid impulse response data is interpolated by using the first-order equation approximation depending on the amount of the extracted time error, and the resulting data is determined as the filter coefficients.

[0189]

While in the present embodiment filter coefficients of the sampling interval twice that of the AD converter 1d is considered, from the standpoint of improving the accuracy in interpolating the delay time, it is desired for the rate of sampling to be set to one larger than the twice sampling rate.

Further, while in the present embodiment the approximation method is based on a first-order equation, other approximation system such as one based on a second-order equation, a spline interpolation can be employed.

[0190]

(D-4) Description of First Modification of Delay Filter in Amplitude Extracting Unit According to Present Embodiment

While in the above-described delay filter 14f of the amplitude extracting unit the first-order equation approximation is utilized to calculate the filter coefficients having the delay characteristic, other arrangement such as one shown in FIG. 42, for example, can be applied to the delay filter 14f.

[0191]

The delay filter 14f shown in FIG. 42 is arranged to have delay filter coefficient holding units 25a to 25e, a sectioning determining unit 25f an MUX 25g and a convolution processing unit 25h.

Each of the delay filter coefficient holding units 25a to 25e is a unit for holding filter coefficients for effecting a predetermined amount of delay. That is, the filter coefficient holding unit 25a holds a coefficient for constituting a filter

having a characteristic of a delay time, $td = 0$. The filter coefficient holding unit 25b holds a coefficient for constituting a filter having a delay time of $td = 0.025\mu s$.

[0192]

Further, the filter coefficient holding unit 25c holds a coefficient for constituting a filter having a delay time of $td = 0.05\mu s$. The filter coefficient holding unit 25d holds a coefficient for constituting a filter having a delay time of $td = 0.075\mu s$. And the filter coefficient holding unit 25e holds a coefficient for constituting a filter having a delay time of $td = 0.1\mu s$.

[0193]

The sectioning determining unit 25f is supplied with the delay time information td from the delay time calculating unit 14e and examines which of the following five sections the value of the delay time td falls into.

That is, if the delay time td is equal to or larger than 0ns and smaller than 12.5ns, the section to fall into is determined be "0". If the delay time td is equal to or larger than 12.5ns and smaller than 37.5ns, the section to fall into is determined be "1". If the delay time td is equal to or larger than 37.5ns and smaller than 62.5ns, the section to fall into is determined be "2". If the delay time td is equal to or larger than 62.5ns and smaller than 87.5ns, the section to fall into is determined be "3". And if the delay time td is equal to or larger than 87.5ns and smaller than 100ns, the section to fall into is determined be "4".

[0194]

The MUX 25g is a unit for taking out filter coefficients from a desired delay filter coefficient holding unit 25a to 25e in accordance with the delay time section determined by the section determining unit 25f and outputting the coefficients to the subsequent convolution processing unit 25h.

For example, the MUX 25g selects coefficients from the section determining unit 25f in such a manner that if it is determined that the delay time section is "0", then filter coefficients are taken out from the delay filter coefficients holding unit 25a, if it is determined that the delay time section is "1", then filter coefficients are taken out from the delay filter coefficients holding unit 25b, if it is determined that the delay time section is "2", then filter coefficients are taken out from the delay filter coefficients holding unit 25c, if it is determined that the delay time section is "3", then filter coefficients are taken out from the delay filter coefficients holding unit 25d, and if it is determined that the delay time section is "4", then filter coefficients are taken out from the delay filter coefficients holding unit 25e. Then, the selected coefficients are supplied to the convolution processing unit 25h.

[0195]

Further, the convolution processing unit 25h is a unit for taking out the coefficients from the MUX 25g and executes the delay processing on the acquired signal (photoelectric converted signal) from the adaptive-type band limiting

differentiating unit 1f.

Also in the above arrangement of the delay filter 14f shown in FIG. 42, convolutional filtering processing can be carried out in such a manner that the gain thereof is set to one until the signal falls within the maximum input signal band in which the signal is allowed to be read as the intensity variation detecting signal, the gain thereof is gradually attenuated as the band thereof is remote from the maximum input signal band, and the signal is delayed in accordance with the amount of time error calculated by the delay time calculating unit 14e. In this way, the signal can undergo the differentiating processing effected at every timing point at which the time error is calculated, and this signal having undergone the differentiating processing can be delayed by an amount corresponding to the aforesaid time error.

[0196]

In more concretely, when the coefficients for the filter processing are determined, a plurality of filter coefficient sets are prepared in advance in the delay filter coefficient holding units 25a to 25e so as to implement a plurality of delay filter characteristics corresponding to the time error amounts extracted (calculated) by the delay time calculating unit 14e. The sectioning determining unit 25f determines which filter processing characteristic of the plurality of filter characteristics is appropriate for the extracted time error amount. Then, the MUX 25g selects a set of filter coefficients implementing the filter characteristic suitable for the result

of determination made by the sectioning determining unit 25f.

[0197]

(D-5) Description of Second Modification of Delay Filter
in Amplitude Extracting Unit of Present Embodiment

In addition to the arrangements shown in FIGS 39 and 42, an arrangement shown in FIG. 43 may be employed for the delay filter 14f. That is, this delay filter arrangement is composed of a wide band LPF characteristic coefficient holding unit 43a, a phase characteristic giving unit 43b, a multiplying unit 43c, an IFFT 43d and a convolution processing unit 43e. In this arrangement, an IFFT processing may be employed for calculating filter coefficients having a delay characteristic in accordance with the delay time calculated by the delay time calculating unit 14e.

[0198]

The wide band LPF characteristic coefficient holding unit 43a is a unit for holding filter coefficients having an LPF gain characteristic in which the signal of the inputted maximum frequency of the photoelectric converted bar code signal is passed at a gain of -1 and signals of frequencies equal to or smaller than that frequency are passed at an attenuated gain. The characteristic to be held in this unit may be set to one shown in FIG. 44, for example.

[0199]

The aforesaid filter characteristic shown in FIG. 44 can be expressed as a gain characteristic of the following Equations (31) to (33).

$$1 : 0 \leq f \leq 2.5 \text{MHz}, 7.5 \text{MHz} \leq f \leq f_s \quad \cdots(31)$$

$$\cos^2((f - (f_c - f_x))\pi / (4*f_x)) \\ : 2.5 \text{MHz} \leq f < 5 \text{MHz} \quad \cdots(32)$$

$$\cos^2((f - (f_{c'} - f_{x'}))\pi / (4*f_{x'})) \\ : 5 \text{MHz} \leq f < 7.5 \text{MHz} \quad \cdots(33)$$

In the above Equations (31) to (33), $f_c = 3.75 \text{MHz}$, $f_x = 1.25 \text{MHz}$, $f_{c'} = 3.75 \text{MHz}$, $f_{x'} = 1.25 \text{MHz}$. This characteristic value is equally divided into n sections at the sampling frequency f_s , and resulting respective values are denoted $G = g_0$ to g_{n-1} (n is a number of exponent for two).

[0200]

The phase characteristic giving unit 43b is a unit for giving a delay phase characteristic for the subsequent convolution processing unit 43e in accordance with the delay time t_d calculated by the delay time calculating unit 14e. For example, the phase characteristic giving unit gives a phase characteristic delay expressed by the following Equation (34) on the basis of the delay time t_d supplied from the delay time calculating unit 14e. For example, the phase characteristic giving unit can give a phase characteristic shown in FIG. 45 to a signal supplied to the subsequent convolution processing unit 43e.

[0201]

$$\theta = 2\pi f * t_d \quad : 0 \leq f \leq f_s/2 \quad \cdots(34)$$

The multiplying unit 43c is supplied with the gain characteristic (see FIG. 44) from the aforesaid wide band LPF holding unit 43a and a phase characteristic (see FIG. 45) from

the phase characteristic giving unit 43b, whereat a real part (Re) and the imaginary part (Im) are calculated based on the following Equations (35) and (36) to form the numbers into a complex vector.

[0202]

$$Re = G \cdot \cos \theta \quad \cdots(35)$$

$$Im = G \cdot \sin \theta \quad \cdots(36)$$

The IFFT processing unit 43d is a unit for carrying out IFFT calculation processing based on the values of Re and Im calculated by the aforesaid multiplying unit 43c. If a signal subjected to the unit has a gain characteristic and a phase characteristic shown in FIGS. 44 and 45, filter coefficients having a characteristic shown in FIG. 46 can be obtained.

[0203]

Further, the convolution processing unit 43e is a unit for effecting convolution processing on the signal supplied from the adaptive-type band limiting differentiating unit 1f by using the filter coefficients obtained by the IFFT processing unit 43d. This convolution processing unit may be composed of a digital filter such as a transversal filter as one shown in FIG. 3, for example.

Also in the above arrangement of the delay filter 14f shown in FIG. 43, convolutional filtering processing can be carried out in such a manner that the gain thereof is set to one until the signal falls within the maximum input signal band in which the signal is allowed to be read as the intensity variation detecting signal, the gain thereof is gradually attenuated as

the band thereof is remote from the maximum input signal band, and the signal is delayed in accordance with the amount of time error calculated by the delay time calculating unit 14e. In this way, the signal can undergo the differentiation processing effected at every timing point at which the time error is calculated, and this signal having undergone the differentiation processing can be delayed by an amount corresponding to the aforesaid time error.

[0204]

In more concretely, when the coefficients for the filter processing are determined, a filter characteristic function is determined so that the gain thereof is set to one until the signal falls within the maximum input signal band allowing the signal to be read as the intensity variation detecting signal and the gain thereof is gradually attenuated as the band thereof is remote from the maximum input signal band. Then, a function delaying a signal in proportion to the amount of extracted time error is added. The result thereof is subjected to the inverse Fourier transform in the IFFT processing unit 43d. Thus, the coefficients are calculated.

[0205]

(D-6) Description of Tri-State Value Generating Unit According to Present Embodiment

FIG. 47 is a block diagram showing the tri-state value generating unit 11 according to the present embodiment.

As described above, the tri-state value generating unit 11 is arranged to have the LMS 14h for outputting the tri-state

value data composed of "1", "0" and "-1" by automatically equalizing the amplitude data 14q extracted at every module timing. The tri-state value generating unit also is arranged to have the wave error determining unit 14i for carrying out data error determination on the amplitude data which is formed into the tri-state values by the LMS 14h.

[0206]

In other words, the LMS 14h can automatically equalize the amplitude data extracted by the amplitude extracting unit 1k at every module timing so as to make it possible to correct the amplitude distortion or the phase distortion caused by the bar code state (concave/convex portions, blurred portion or the like) or the analog circuits containing elements such as a pin-photo diode employed in the photo receiving section 1b. The LMS 14h is further arranged to have a convolution processing unit 26a, a coefficient correction determining unit 26b, a filter coefficient calculating unit 26c and a tri-state value determining unit 26d.

[0207]

The convolution processing unit 26a is a unit for effecting the convolution processing by using filter coefficients calculated by the filter coefficient calculating unit 26c, which will be described later on. As shown in more detail in FIG. 48, the arrangement thereof is composed of a digital filter having five tap coefficients X0 to X4.

As shown in FIG. 48, the convolution processing unit 26a is arranged to have a gain corrected coefficient holding unit

48a-1, a multiplying unit 48a-2, delaying units 48b-1 to 48b-5, multiplying units 48c-1 to 48c-5, adding units 48d-1 to 48d-5, a sum calculating unit 48e and a multiplying unit 48f.

[0208]

The multiplying unit 48a-2 is a unit for multiplying the amplitude value data supplied from the amplitude extracting unit 1k at every module timing with a coefficient held in the gain corrected coefficient holding unit 48a-1. The delaying units 48b-1 to 48b-5 are connected to one another in a cascade fashion. Each of the delaying units is supplied with the amplitude value data from the multiplying unit 48a-2 and responds to the module timing as a clock to shift the data for the subsequent delaying unit.

[0209]

That is, the delaying units 48b-1 to 48b-5 function as a shift register. For example, of the data pieces shown in FIG. 49, the amplitude value data piece at an older timing is sequentially shifted for the subsequent stage as the amplitude value data in response to the module timing as a clock.

For example, the amplitude value data pieces d4 to d0 shown in FIG. 49 are held at the taps X0 to X4 of the delaying units 48b-1 to 48b-5, and after one module timing elapses from that timing point, the data pieces are shifted. At this timing point, the amplitude value data pieces d5 to d1 are held at the delaying units 48b-1 to 48b-5 in series.

[0210]

The multiplying units 48c-1 to 48c-5, the adding units

48d-1 to 48d-5 and the sum calculating unit 48e are collectively arranged to calculate the sum of multiples each of which derives from multiplying the tap stored in each delaying unit 48b-1 to 48b-5 and a tap coefficient supplied from a tap coefficient holding unit 48o-1 to 48o-5, which will be described later on, together. The multiplying unit 48f is a unit for multiplying the data supplied from the sum calculating unit 48e by the coefficient k (in the case of FIG. 48, k = "4").

[0211]

Accordingly, it follows that the delaying units 48b-1 to 48b-5, the multiplying units 48c-1 to 48c-5, the adding units 48d-1 to 48d-5, the sum calculating unit 48e, and the multiplying unit 48f are in the convolution processing unit 26a are arranged to collectively carry out a convolution calculation expressed in the following Equation (37).

Sn

$$= k * (X0*C0 + X1*C1 + X2*C2 + X3*C3 + X4*C4)$$

...(37)

Further, the coefficient correction determining unit 26b is a unit for carrying out least-squares method for correcting the distortions of the amplitude and the phase contained in the width length data when the amplitude values extracted by the amplitude extracting unit 11 are examined as the tri-state value data and outputted therefrom.

[0212]

In more concretely, the coefficient correction determining unit 26b examines which of the three numbers, or

"+1", "0", "-1", the result Sn of the convolution processing corresponds to. Only if it is determined that the result of convolution processing obviously corresponds to any of the three numbers, "+1", "0", "-1", then the coefficient correction determining unit outputs an error Err indicating an error relative to a reference value. Conversely, if it is determined that there is no value in any of the three numbers to which the result of convolution processing obviously corresponds, the value of Err is set to zero and this value is generated therefrom. The coefficient correction determining unit is arranged to have a corresponding number determining unit 48g, a g0 multiplying unit 48h, a Cdc coefficient holding unit 48i and an adding unit 48j.

[0213]

The filter coefficient calculating unit 26c is a unit for calculating tap coefficients C0 to C5 utilized for the convolution processing in the aforesaid convolution processing unit 26a based on the error value Err supplied from the aforesaid determining unit 26b. The filter coefficient calculating unit is arranged to have an α -multiplying unit 48k, multiplying units 48m-1 to 48m-5, adding units 48n-1 to 48n-5, and the tap coefficient holding units 48o-1 to 48o-5.

[0214]

Owing to the operations of the α -multiplying unit 48k, the multiplying units 48m-1 to 48m-5, the adding units 48n-1 to 48n-5, and the tap coefficient holding units 48o-1 to 48o-5, the tap coefficients C0 to C4 can be determined based on the

following Equations (38) to (42). In the following Equations (38) to (42), α represents a convergence factor and the value thereof is selected from a range of $0 < \alpha < 1$.

[0215]

$$C_0 = C_0 + \alpha * Err \quad \dots(38)$$

$$C_1 = C_1 + \alpha * Err \quad \dots(39)$$

$$C_2 = C_2 + \alpha * Err \quad \dots(40)$$

$$C_3 = C_3 + \alpha * Err \quad \dots(41)$$

$$C_4 = C_4 + \alpha * Err \quad \dots(42)$$

The tri-state value determining unit 26d shown in FIG. 47 is a unit for carrying out tri-state value determination on the amplitude value data having undergone the convolution processing in the convolution processing unit 26a based on an operation of comparison relative to a fixed slice level. That is, the multiplying unit 48a-2 provided in the convolution processing unit 26a, which is disposed on the preceding stage with respect to the tri-state value determining unit, carries out correction of comparison by using the fixed slice level ("± 0.5"), whereby the tri-state value determination can be effected.

[0216]

In more concretely, if the amplitude value data supplied from the convolution processing unit 26a and the fixed slice level "+0.5" are compared with each other, and as a result, it is determined that the amplitude value data is larger than the fixed slice level, then the amplitude value is determined as "+1" and the value is outputted therefrom. Conversely, if the amplitude value data and the fixed slice level "-0.5" are compared

with each other, and as a result, it is determined that the amplitude value data is smaller than the fixed slice level, then the amplitude value is determined as "-1" and the value is outputted therefrom. Further, if it is determined that the amplitude value data falls within a range between the aforesaid two fixed slice levels, or "-0.5" and "+0.5", then the amplitude value is determined as "0" and the value is outputted therefrom.

[0217]

Further, the wave error determining unit 14i shown in FIG. 47 is a unit for determining an error of the amplitude value data having undergone the tri-state value determination in the LMS 14h in a manner concretely illustrated in FIG. 50. In more concretely, when the amplitude value of the signal taken out by the amplitude extracting unit 1k is determined as a data piece of "+1" or "-1" and outputted therefrom, of amplitude values of signal points having the same sign and neighboring one another, the largest point is determined as a point of "+1" and the smallest point is determined as a point of "-1". Further, an amplitude value other than those determined as a point of "+1" or "-1" is determined as a point of "0".

[0218]

In a general case, the differentiated signal (see a waveform shown at reference 29b in FIG. 50) having undergone the band limiting in the adaptive-type band limiting differentiating unit 1f takes a value of "+1" or "-1" at the boundary point 29g and a value of "0" at a flat portion 29h having no color change of the white or black region of the bar code.

However, if the bar code printed face has a concave/convex portion or a blurred portion causing a noise or other factors causing reading error, a wave error (Wave Error) can be bought about in the aforesaid tri-state value determining unit 26d. That is, the aforesaid tri-state value determining unit can erroneously determine "+1" for a true determination "0", "0" for a true determination "+1", or "0" for a true determination "-1", and so on.

[0219]

In this case, according to the wave error determining unit 14i of the present embodiment, if the amplitude value data pieces of the signal points adjacent to each other have the same sign (Eye values such as signal points A1 and A2 on the waveform 29c shown in FIG. 50, for example), these two amplitude values of the signal points are compared with each other. Then, correction is made in such a manner that a signal point having the larger amplitude value is determined as "+1" and the remaining point is determined as "0".

In the case of the diagram of FIG. 50, the signal points A1 and A2 adjacent to each other are assigned with "+1" as a result of determination of the tri-state value determining unit 26d. However, the wave error determining unit 14i compares the magnitude of the amplitude values of the signal points A1 and A2 with each other, and correction is made in such a manner that a signal point having the larger amplitude value is determined as "+1" and the remaining point is determined as "0" (see reference 29f in FIG. 50).

[0220]

According to the above-described arrangement of the LMS 14h of the tri-state value generating unit 11, in the convolution processing unit 26a, respective amplitude values extracted at every module timing are stored in the delaying units (taps X0 to X4) 48b-1 to 48b-5, and the amplitude values stored in the delaying units 48b-1 to 48b-5 are shifted in response to the module timing serving as a clock, respectively.

[0221]

In the convolution processing unit 26a, the amplitude values stored in the delaying units 48b-1 to 48b-5 and the filter coefficients calculated by the filter coefficient calculating unit 26c are utilized for carrying out the convolution calculation expressed by the aforesaid Equation (37) in response to each module timing, for example. The tri-state value determining unit 26d examines which of the values "+1", "0", "-1" the result S_n of the convolution processing corresponds to.

[0222]

When the aforesaid convolution processing unit 26a and the tri-state determining unit 26d carry out determination on the data having undergone the tri-state data forming process and output the resultant data therefrom, the coefficient correction determining unit 26b effects the least-squares method to correct the distortion in the amplitude and the phase contained in the width length data signal. In more concretely, a certain value ranges are prepared and only if it is determined that the

result obviously corresponds to any of the three numbers, "+1", "0", "-1", then the coefficient correction determining unit outputs an error Err as an error with respect to the reference value. Conversely, if it is determined that there is no value obviously corresponding to any of the three numbers, the value of Err is set to "zero" and this value is generated therefrom.

[0223]

The value of Err is subjected to the aforesaid calculation processing expressed by equations (38) to (42) concerning the respective filter coefficient values C0 to C5. In response to the subsequent module timing, the convolution calculation using the tap coefficients calculated as described above is carried out in the convolution processing unit 26a. However, also the coefficient correction determining unit 26b carries out the filter coefficient calculation using the new convergence factor α .

[0224]

If the value of Err is equal to or smaller than a certain value, or the processing goes through a predetermined number of processing routines, the processing in the LMS 14h is closed. Then, the finally obtained filter coefficients are utilized to carry out the convolution processing together with the amplitude data series at every module timing obtained in the initial step. In this way, intersymbol interference distortion due to the Gaussian beam or the like can be corrected and an eye pattern can be widely opened (see FIG. 51(b)) as compared with a case in which the above-described automatic equalizing processing

is not carried out (see FIG. 51(a)).

[0225]

Further, when the amplitude value of the signal taken out by the amplitude extracting unit 1k is determined as a data piece of "+1" or "-1" and outputted therefrom, the wave error determining unit 14i carries out determination in such a manner that, of amplitude values of signal points having the same sign and neighboring one another, the largest point is determined as a point of "+1", the smallest point is determined as a point of "-1", and an amplitude value other than those determined as a point of "+1" or "-1" is determined as a point of "0".

[0226]

As described above, according to the present embodiment, owing to the tri-state value generating unit 1l, the amplitude values extracted in accordance with the timing point can be led as tri-state value formulated data. Therefore, it becomes possible to suppress the size of hardware and a price thereof and to improve an S/N ratio of a reading signal and reading resolution. Moreover, even if depth of field for reading is enlarged or a concave/convex portion or a blurred portion is left on the reading face, reading precision can be improved.

[0227]

Moreover, the LMS 14h brings advantages particularly when photoelectric converted signal of a reflected ray of a Gaussian beam is acquired as an acquired signal. That is, owing to this unit, delay or distortion due to a group of circuits can be corrected together with the distortion due to the intersymbol

interference caused by the Gaussian beam or the like, with the result that the aforesaid reading resolution can be remarkably improved.

(E) Description of Example of Characteristic of Bar Code Reading Apparatus According to Present Embodiment

According to the above-described bar code reading apparatus of the present embodiment, as shown in FIGS. 1 or 52, a light beam emitted from the laser diode 1a-1 is refracted by a mirror or the like, although not shown, so as to lead into the polygon mirror 1a-2.

[0228]

The polygon mirror 1a-2 can be rotated at a rate of $R[\text{rpm}]$ so that the light beam refracted by the polygon mirror 1a-2 can be led as a scanning beam to the outside of the apparatus housing. A plural number of mirrors may be provided so that a multi-pattern scanning is created by the scanning beam.

In this case, as shown in FIG. 52, $L_0[m]$ is taken as a distance from a glass window, which serves as a boundary between the internal space of the apparatus housing and the outside thereof, to the polygon mirror 1a-2 as an emitting point. $L_1[m]$ is taken as a distance (depth of field for reading) from the glass window to the bar code as a target of reading. Then, a beam speed $v[m/s]$ upon scanning the bar code can be expressed by the following Equation (43).

[0229]

$$\begin{aligned} v &= (L_0 + L_1) * \omega \\ &= (L_0 + L_1) * (R[\text{rpm}] * 1/60 * 2\pi) \end{aligned} \quad \cdots(43)$$

Then, as shown in FIG. 53, if one module width of the minimum readable bar code is set to $\text{bar}[m]$, the depth of field for reading thereat $L_{\text{max}}[m]$, and the beam speed thereof $v_{\text{max}}[\text{m/s}]$, then the beam speed can be given as Equation (44). Thus the frequency f_{mod} , which is half the elemental frequency (module frequency), can be expressed by Equation (45).

[0230]

$$v_{\text{max}} = (L_0 + L_{\text{max}}) * (R * 2\pi / 60) \quad \cdots(44)$$

$$f_{\text{mod}} = 2 * \text{bar} / v_{\text{max}}$$

$$= 2 * \text{bar} / ((L_0 + L_{\text{max}}) * (R * 2\pi / 60)) \quad \cdots(45)$$

As a consequence, by using f_{mod} obtained by the above Equation (45) and the sampling frequency f_s of the AD converter 1d, f_s/f_{mod} can be calculated. This value serves as an index expressing the fineness of sampling.

[0231]

FIG. 54(a) is a table showing values of f_{mod} obtained by using the aforesaid Equation (45) under the variable conditions of m_{ug} , bar and the beam speed v . The values of f_{mod} obtained by the above process are applied to the bar code reading apparatus according to the present embodiment. FIGS. 54(b), 54(c) and 54(d) are each table showing the result of calculation on the f_s/f_{mod} under the condition that the sampling frequency f_s is set to any of 5MHz, 10MHz and 20MHz, respectively.

[0232]

If it is desired to achieve bar code reading performance with the values of m_{ug} , bar listed in FIG. 54(b) to 54(d) by a conventional type of bar code reading apparatus, a sampling

frequency f_s of 40MHz is requested. In this case, values of f_s/f_{mod} become as shown in FIG. 54(e). That is, as shown in FIG. 54(e), about ten times or more fineness in the sampling frequency is requested under all value setting conditions.

[0233]

Conversely, according to the bar code reading apparatus of the present embodiment, if the reading conditions composed of the values of mug, bar and so on are set in the same manner as those shown in FIG. 54(e), reading can be executed at a relatively low frequency. Therefore, even if the value of f_s/f_{mod} is set in accordance with the following Equation (46), the required bar code reading accuracy will be satisfactorily secured.

[0234]

$$2 < f_s/f_{mod} \leq 10 \quad \cdots (46)$$

The above equation can be held in the present invention.

Accordingly, also in this case, the reading apparatus is not requested to have a circuit capable of handling a wide band characteristic on the receiving side thereof. Moreover, if the signal-to-noise ratio (S/N) is improved, the reading area can be enlarged, the reading resolution can be improved and the reading accuracy can be improved even when the medium itself contains a cause of reading noise. Furthermore, the reading apparatus can be free from being equipped with a clock operated at a high rate in order for measuring the elemental unit length of the information length of the binary digit information. Therefore, even if the sampling accuracy is lowered, the reading

accuracy of the binary digit information can be kept high, and cost performance in hardware constituting the apparatus will be improved while the performance of the apparatus is enhanced.

[0235]

A bar code reading apparatus having the aforesaid value of $fs/fmod$ set to "10", "20" or more can be realized without any difficulty as an implementation of the present invention.

(F) Other Disclosure

While the above-described embodiment is concerned with a bar code reading apparatus for reading bar code information contained in a bar code, the present invention can be applied to a case in which reading is effected on a medium having recorded thereon a mark other than the bar code having a data group expressed by information elements with a width length data composed of a white region and a black region, the white region and the black region being alternately disposed to construct a predetermined pair of information elements, and the information composed of the data groups are read as an integer ratio between each width length data pair.

[0236]

Further, the present invention does not require an assumption that the information of data group is read from the above-described medium as an integer ratio of each width length data pair. That is, the present invention can be applied to a case in which acquisition is made on a signal containing binary digit information simply deriving from information elements having a predetermined information length and arrayed

one-dimensionally, and information reading is executed on the ratio of information length of the binary digit information.

Further, as described above, the bar code reading apparatus according to the above-described present embodiment is provided with the AD converter 1d on the input side of the reading processing section 1C and the reading processing section 1C is arranged to carry out the cut-out processing by using a digital signal processing. However, particularly, the function unit for carrying out the digital signal processing may be composed of firmware or the like. Also, it is reasonable choice to construct the function unit with software or hardware.

[0237]

Further, if an arrangement is made on the reading processing section 1C shown in FIG. 1 so as to omit the AD converter 1d on the input side thereof, an analog signal processing may be introduced so as to replace for the aforesaid cut-out unit 1e, the module frequency extracting unit 1g and the band limiting differentiation processing unit 1h. In this case, an option can be selected in such a manner that a function for carrying out the A/D conversion processing is provided in the decimation processing unit 1h'.

[0238]

Furthermore, processing imposed on respective processing units of the bar code reading apparatus according to the present embodiment may be separately imposed on a plurality of printed board modules, card modules and so on which are operated by firmware, hardware circuit and so on. Also, the same processing

may be imposed on an information processing apparatus operated in accordance with a software.

For example, as shown in FIG. 55, a printed board module 1D may be introduced and this printed board module 1D is connected to an information processing terminal 1F. Thus, the whole system is made to serve as the aforesaid bar code reading apparatus shown in FIG. 1.

[0239]

That is, the printed board module 1D is made to have functions of the cut-out unit 1e, the adaptive-type band limiting differentiating unit 1f and the every module point amplitude extracting unit 1i shown in FIG. 1. Also, the information processing terminal operated in accordance with a software may be made to have functions of the module number calculating unit 1m and the character arrangement checking unit 1n.

[0240]

In other words, the printed board module 1D shown in FIG. 55 can function as a read signal processing unit having the module frequency extracting unit 1g, the band limiting differentiation processing unit 1h and the every module point amplitude extracting unit 1i, the module frequency extracting unit acquiring a signal (see "W" or "B" shown at reference 6a in FIG. 10) containing the binary digit information of information elements having a predetermined information length and arrayed in a one-dimensional manner and also serving as means for extracting the elemental frequency (module frequency) corresponding to the elemental unit length (module length) of

the information length of the binary digit information from the acquired signal, the band limiting differentiation processing unit and the every module point amplitude extracting unit serving as units for effecting the band limiting processing on the acquired signal based on the extracted elemental frequency information and thereafter extracting boundary information of the binary digit information.

[0241]

In addition to the aforesaid example of FIG. 55, an arrangement can be made as shown in FIG. 56. That is, as shown in FIG. 56, a printed board module 1E as a read signal processing unit and an information processing terminal 1G connected with the printed board module 1D will function as the bar code reading apparatus.

That is, the printed board module 1E is made to have functions of the cut-out unit 1e, the adaptive-type band limiting differentiating unit 1f, the every module point amplitude extracting unit 1i and the module number calculating unit 1m shown in FIG. 1. Also, the information processing terminal operated in accordance with a software may be made to have a function of the character arrangement checking unit 1n.

[0242]

In other words, the printed board module 1E shown in FIG. 56 can function as a read signal processing unit having the module frequency extracting unit 1g, the band limiting differentiation processing unit 1h, the every module point amplitude extracting unit 1i and the module number calculating unit 1m, the module

frequency extracting unit acquiring a signal containing the binary digit information of information elements having a predetermined information length and arrayed in a one-dimensional manner and also serving as means for extracting the elemental frequency (module frequency) corresponding to the elemental unit length of the information length of the binary digit information from the acquired signal, the band limiting differentiation processing unit, the every module point amplitude extracting unit and the module number calculating unit serving as units for effecting the band limiting processing on the acquired signal based on the extracted elemental frequency information and thereafter extracting a ratio of information length of the binary digit information.

[0243]

Accordingly, the read signal processing unit is arranged to have the module frequency extracting unit 1g as means for extracting the elemental frequency and the every module point amplitude extracting unit 1i as means for extracting the boundary information of the binary digit information. Therefore, at least a function carrying out the processes of from the band limitation to the tri-state value generation can be separately provided from other function units. Thus, the portion of the read signal processing unit can independently find extensive application field of processing in other information processing apparatus, with the result that the apparatus can be more generally utilized and the apparatus arrangement comes to have a large variation.

[0244]

(Additional Note 1) A method of reading information characterized by comprising steps of acquiring from a medium, a signal containing binary digit information having a predetermined information length and a one-dimensional arrangement, extracting information concerning an elemental unit length of the information length of the binary digit information from the acquired signal, and reading a ratio of the binary digit information to the information length based on the extracted elemental unit length information.

[0245]

(Additional Note 2) A method of reading information according to Additional Note 1, characterized in that the elemental unit length information is extracted as an elemental frequency information corresponding to the elemental unit length, a band limiting processing is effected on the acquired signal based on the extracted elemental frequency information, and thereafter the ratio of the information length of the binary digit information is read.

(Additional Note 3) A method of reading information according to Additional Note 2, characterized in that a periodic signal is generated so as to be synchronism with the acquired signal and have an elemental frequency corresponding to the elemental unit length, whereby the elemental unit length information is extracted.

[0246]

(Additional Note 4) An information reading apparatus

characterized by comprising:

a signal acquiring unit for acquiring from a medium, a signal containing binary digit information having a predetermined information length and an arrangement;

an elemental frequency extracting unit for extracting an elemental frequency corresponding to an elemental unit length of the binary digit information of the information length from the acquired signal;

a band limiting unit for limiting a frequency band of the acquired signal based on the extracted elemental frequency information;

a timing point extracting unit for extracting a timing point which is in synchronism with the acquired signal and has the elemental frequency, based on the acquired signal and the elemental frequency information;

an amplitude extracting unit for extracting an amplitude value of a signal from the band limiting unit in accordance with the timing point extracted by the timing point extracting unit;

a tri-state value generating unit for generating tri-state value data from the amplitude values extracted by the amplitude extracting unit in accordance with the timing point; and

a reading unit for reading a ratio of the binary digit information to the information length by calculating the tri-state value data generated by the tri-state value generating unit.

[0247]

(Additional Note 5) An information reading apparatus

according to Additional Note 4, characterized in that the signal acquiring unit comprises a photoelectric converting unit for receiving a ray of incident light and converting the received ray of light into an electric signal based on the photoelectric conversion, a determining unit for determining whether the electric signal supplied from the photo-electric converting unit derives from photo-electric conversion effected on the ray of light reflected on the medium or not, and a gate unit arranged to respond to the result of determination of the determining unit in such a manner that if it is determined that the signal component derives from photoelectric conversion effected on the reflected ray of light then the signal component is acquired as the acquired signal while if it is determined that the signal component derives from photoelectric conversion effected on any ray of light other than the reflected ray of light then the signal component is excluded from an object of a signal to be acquired.

[0248]

(Additional Note 6) An information reading apparatus according to Additional Note 5, characterized by an arrangement such that the determining unit is supplied with a signal deriving from conversion from an analog signal status to a digital signal status effected on the electric signal from the photoelectric converting unit, and the determining unit determines whether the signal derives from photoelectric conversion effected on the ray of light reflected on the medium or not.

(Additional Note 7) An information reading apparatus for reading information from a medium having a mark representing

a data group composed of a predetermined number of pairs of information elements, each of the information elements being composed of a white region and a black region disposed alternately with a certain width arranged to have an association with coded data, the information reading apparatus acquiring the data group information as an integer number ratio between the data widths of each information element pair, the information reading apparatus comprising:

a signal acquiring unit for detecting an analog signal having a variation corresponding to an intensity variation of a reflected ray of light which is caused by scanning the mark on the medium with a ray of light running at a predetermined velocity in the scanning direction, and effecting a sampling operation on the continuous signal at a predetermined sampling frequency to acquire the data group information represented by the mark recorded on the medium in a form of digital signal;

an elemental frequency extracting unit for extracting an elemental frequency corresponding to an elemental unit length of the width of the white region and the black region from the acquired signal in the form of digital signal;

a band limiting unit for limiting a frequency band of the acquired signal based on the extracted elemental frequency information;

a timing point extracting unit for extracting a timing point which is in synchronism with the acquired signal and has the elemental frequency, based on the acquired signal and the elemental frequency information;

an amplitude extracting unit for extracting an amplitude value of a signal from the band limiting unit in accordance with the timing point extracted by the timing point extracting unit;

a tri-state value generating unit for generating tri-state value data from the amplitude values extracted by the amplitude extracting unit in accordance with the timing point; and

a reading unit for reading a ratio of the binary digit information to the information length by calculating the tri-state value data generated by the tri-state value generating unit, wherein

relationship among a width, bar[μ m] of the white region or the black region representing the elemental unit length of the binary digit information, the scanning velocity, vmax[m/s] of the scanning ray of light, and the sampling frequency, fs[MHz] can be expressed by the following equation

$$2 < \frac{fs}{(2 * bar / vmax)} \leq 10$$

[0249]

(Additional Note 8) A method of acquiring a signal for use with an information reading apparatus having a signal acquiring unit for acquiring a signal containing binary digit information recorded on a medium so as to have a predetermined information length, the information reading apparatus being arranged to extract information regarding an elemental unit length of the information length of the binary digit information from the acquired signal, thereby to read a ratio of the binary digit information to the information length based on the extracted elemental unit length information, the method of

acquiring a signal for use with the information reading apparatus characterized in that

the signal acquiring unit acquires a signal containing the signal component and also a component other than one deriving from the medium having the binary digit information recorded thereon, determination is made on the acquired signal so as to identify a signal portion deriving from the medium having the binary digit information recorded thereon by using an amplitude averaging calculation processing, and

the signal component deriving from the medium is cut out in accordance with the result of determination, and the cut-out portion is acquired as a signal containing the binary digit information.

[0250]

(Additional Note 9) A method of effecting a band limiting processing for use with an information reading apparatus having a signal acquiring unit for acquiring a signal containing binary digit information recorded on a medium so as to have a predetermined information length, the information reading apparatus being arranged to extract information regarding an elemental unit length of the information length of the binary digit information from the acquired signal, thereby to read a ratio of the binary digit information to the information length based on the extracted elemental unit length information, the method of effecting a band limiting processing for use with the information reading apparatus characterized in that

as a preprocessing for reading the ratio data of the binary

digit information to the information length, an elemental frequency corresponding to the elemental unit length is extracted from the acquired signal, and the frequency band of the acquired signal is limited based on the extracted elemental frequency.

[0251]

(Additional Note 10) A method of extracting a timing point amplitude for use with an information reading apparatus having a signal acquiring unit for acquiring a signal containing binary digit information recorded on a medium so as to have a predetermined information length, an elementary frequency extracting unit for extracting an elementary frequency corresponding to an elementary unit length of the information length of the binary digit information obtained from the acquired signal, and a band limiting unit for limiting a frequency band of the acquired signal based on the extracted elemental frequency information, wherein a ratio of the binary digit information to the information length is read from the signal having undergone the frequency band limitation in the band limiting unit, the method of extracting the timing point amplitude for use with the information reading apparatus characterized in that

as a preprocessing for reading the ratio data of the binary digit information to the information length, a timing point in synchronism with the acquired signal and having the elemental frequency is extracted based on the acquired signal and the elemental frequency information, an amplitude value of a signal from the band limiting unit is extracted in accordance with the extracted timing point, and tri-state value data is generated

from the extracted amplitude values in accordance with the timing point.

[0252]

(Additional Note 11) A method of reading information from a medium having a mark recorded thereon, the mark representing a data group composed of a predetermined number of information element pairs each composed of a white region and a black region each having a width length and disposed alternately on the mark for representing the data group, the method of reading information achieving information reading by acquiring the data group information as an integer number ratio between the width length data of each information element pair, characterized by comprising steps of:

scanning a ray of light on the mark at a predetermined velocity to cause a reflected ray of light, detecting a signal having a variation corresponding to an intensity variation of the reflected ray of light deriving from the scanning in the scanning direction, thereby acquiring a signal containing binary digit information corresponding to the intensity variation of the reflected ray of light;

extracting an elemental frequency corresponding to an elemental width time of the width data from the acquired signal;

effecting band limitation on the acquired signal to obtain an optimum signal band based on the extracted elemental frequency; and

reading integer number ratio between the data widths of each information element pair from the acquired signal having

undergone the band limitation based on the elemental frequency.

[0253]

(Additional Note 12) A method of reading information according to Additional Note 11, characterized in that each processing from a step of acquiring the detected signal having the intensity variation in the reflected ray of light to a step of reading the integer number ratio between the width length data of each information element pair contains a differential processing characteristic of a time span substantially corresponding to the elemental width time or a time span substantially corresponding to one slightly smaller than the elemental width time.

(Additional Note 13) A method of reading information according to Additional Note 11, characterized in that each processing from a step of acquiring the detected signal having the intensity variation in the reflected ray of light to a step of reading the integer number ratio between the width length data of each information element pair contains a differentiating processing characteristic of a gain peak frequency substantially corresponding to the elemental frequency equivalent to the elemental width time or a frequency substantially corresponding to one slightly larger than the elemental frequency.

[0254]

(Additional Note 14) A method of reading information according to Additional Note 13, characterized in that the differentiating processing characteristic is arranged to have a gain characteristic of a cosine equivalent characteristic

having a gain peak frequency substantially corresponding to the elemental width time of the width information of the input signal or a gain peak frequency substantially corresponding to one slightly larger than the gain peak frequency whereas the differentiating processing characteristic is arranged to have a phase characteristic tending to vary linearly with respect to the frequency.

[0255]

(Additional Note 15) A method of reading information according to Additional Note 13, characterized in that the differentiating processing characteristic is arranged to have a gain characteristic of a squared-cosine equivalent characteristic having a gain peak frequency substantially corresponding to the elemental width time of the width information of the input signal or a gain peak frequency substantially corresponding to one slightly larger than the gain peak frequency whereas the differentiating processing characteristic is arranged to have a phase characteristic tending to vary linearly with respect to the frequency.

[0256]

(Additional Note 16) A method of reading information according to Additional Note 11, characterized in that the step of extracting the elemental frequency is further arranged to comprise steps of:

effecting a differentiating processing on the acquiring signal in such a manner that the gain peak frequency is set to a value equal to or larger than the maximum frequency of the

acquired signal in a signal acquisition allowable region;

effecting a squaring processing on a signal having undergone the differentiating processing;

analyzing the result deriving from the squaring processing based on frequency spectrums; and

determining that a significant certain frequency except for 0Hz is regarded as the elemental frequency based on the result of analysis using the frequency spectrums.

[0257]

(Additional Note 17) A method of reading information according to Additional Note 11, characterized in that the step of extracting the elemental frequency is further arranged to comprise steps of:

effecting a differentiating processing on the acquiring signal in such a manner that the gain peak frequency is set to a value equal to or larger than the maximum frequency of the acquired signal in a signal acquisition allowable region;

effecting a squaring processing on a signal having undergone the differentiating processing;

analyzing the result deriving from the squaring processing based on frequency spectrums;

determining that a significant certain frequency except for 0Hz is regarded as the elemental frequency based on the result of analysis using the frequency spectrums;

effecting demodulating processing on the signal having undergone the squaring processing based on the frequency obtained by the frequency calculation and forming the signal into a vector;

removing a high frequency component from the signal having undergone the demodulation and the vector formation;

obtaining a phase difference between a signal from which the high frequency component is removed and a signal delayed by one sample time from that signal;

calculating a deviation of the elemental frequency in terms of frequency relative to the obtained elemental frequency based on the above-obtained phase difference; and

determining that the result obtained by adding the calculated frequency deviation to the obtained elemental frequency is the elemental frequency information.

[0258]

(Additional Note 18) A method of reading information according to Additional Note 11, characterized in that when the signal containing the binary digit information is acquired, the manner of signal acquisition is such that the signal is acquired as a digital signal having undergone sampling operation at a predetermined sampling interval, and as a preprocessing for reading the integer number ratio between the width length data of each information element pair, data number decimation is effected on the digital signal having undergone the signal band limitation in accordance with the elemental frequency information.

[0259]

(Additional Note 19) A method of reading information from a medium having a mark recorded thereon, the mark representing a data group composed of a predetermined number of information

element pairs each composed of a white region and a black region each having a width length and disposed alternately on the mark for representing the data group, the method of reading information achieving information reading by acquiring the data group information as an integer number ratio between the width length data of each information element pair, the method characterized by comprising steps of:

scanning a ray of light on the mark at a predetermined velocity to cause a reflected ray of light, detecting a signal having a variation corresponding to an intensity variation of the reflected ray of light deriving from the scanning in the scanning direction, thereby acquiring a signal containing binary digit information corresponding to the intensity variation of the reflected ray of light;

extracting a timing point containing the width data from the acquired signal; and

reading the integer number ratio between the data widths of each information element pair from the mark in accordance with the extracted timing point.

[0260]

(Additional Note 20) A method of reading information according to Additional Note 19, characterized in that when the timing point is extracted, differentiating processing is effected on the acquired signal, a timing point is specified in the signal having undergone the differentiating processing in order that the information length of the binary digit information recorded on the medium can be read, and tri-state

value digital information is extracted from the amplitude of the signal having undergone the differentiating processing at every specified timing point.

[0261]

(Additional Note 21) A method of reading information according to Additional Note 20, characterized in that when the timing point is extracted, a frequency signal corresponding to the elemental time width of the information length of the binary digit information is extracted from the signal having undergone the differentiating processing, and the extracted frequency signal is utilized to specify the timing point in the signal having undergone the differentiating processing.

[0262]

(Additional Note 22) A method of reading information according to Additional Note 20, characterized in that when the timing point is extracted, a periodic signal corresponding to the elemental time width of the information length of the binary digit information is extracted from the signal having undergone the differentiating processing, and the extracted frequency signal is utilized to specify the timing point in the signal having undergone the differentiating processing.

[0263]

(Additional Note 23) A method of reading information according to Additional Note 20, characterized in that when the tri-state digital information is extracted, an amplitude value is taken out from the signal having undergone the differentiating processing at every specified timing point, and the taken-out

amplitude value of the signal is converted into tri-state value digital data.

(Additional Note 24) A method of reading information according to Additional Note 19, characterized in that when the timing point is extracted, differentiation processing is effected on the acquired signal, a frequency component corresponding to the elemental width time of the width length data is extracted while the signal having undergone the differentiation processing is handled as an input signal, a periodic signal is generated so as to correspond to the elemental width time while the signal having undergone the differentiating processing is handled as an input signal, and a timing point corresponding to the existing point of the mark width information is specified while the generated periodic signal is handled as an input signal, whereas

when the integer number ratio between the width length data of each information element pair is read, an amplitude value is taken out from the signal having undergone the differentiation processing at every specified timing point, and the amplitude value of the signal taken out at every specified timing point is converted into tri-state value digital data.

[0264]

(Additional Note 25) A method of reading information according to Additional Note 24, characterized in that when the differentiation processing is effected on the acquired signal, the differentiation processing is carried out by using a frequency as a gain peak frequency which corresponds to the

elemental width time while the acquired signal is handled as an input signal, and a periodic signal is generated so as to correspond to a frequency equivalent to the elemental width time while the resultant signal having undergone the differentiation processing is handled as an input signal.

[0265]

(Additional Note 26) A method of reading information according to Additional Note 24, characterized in that the step of extracting the frequency component corresponding to the elemental width time is further arranged to comprise steps of:

effecting a differentiating processing on the acquired signal in such a manner that the gain peak frequency is set to a value equal to or larger than the maximum frequency of the acquired signal in a signal acquisition allowable region;

effecting a squaring processing on a signal having undergone the differentiation processing;

analyzing the result deriving from the squaring processing based on frequency spectrums; and

determining that a significant certain frequency except for 0Hz is regarded as the elemental frequency based on the result of analysis using the frequency spectrums.

[0266]

(Additional Note 27) A method of reading information according to Additional Note 24, characterized in that the step of extracting the frequency component corresponding to the elemental width time is further arranged to comprise steps of:

effecting a differentiation processing on the acquired

signal in such a manner that the gain peak frequency is set to a value equal to or larger than the maximum frequency of the acquired signal in a signal acquisition allowable region;

effecting a squaring processing on a signal having undergone the differentiation processing;

analyzing the result deriving from the squaring processing based on frequency spectrums;

determining that a significant certain frequency except for 0Hz is regarded as the elemental frequency based on the result of analysis using the frequency spectrums;

effecting demodulation processing on the signal having undergone the squaring processing based on the frequency obtained by the frequency calculation and forming the signal into a vector;

removing a high frequency component from the signal having undergone the demodulation and the vector formation;

obtaining a phase difference between a signal from which the high frequency component is removed and a signal delayed by one sample time from that signal;

calculating a deviation of the elemental frequency in terms of frequency relative to the obtained elemental frequency based on the above-obtained phase difference; and

determining that the result obtained by adding the calculated frequency deviation to the obtained elemental frequency is the elemental frequency information.

[0267]

(Additional Note 28) A method of reading information according to Additional Note 24, characterized in that when the

periodic signal is generated so as to correspond to the elemental width time, the gain characteristic thereof is set to a squared cosine characteristic having a gain peak frequency which is twice the frequency corresponding to the elemental width time, and the phase characteristic thereof is set to a characteristic having no variation in connection with the frequency.

(Additional Note 29) A method of reading information according to Additional Note 24, characterized in that when the periodic signal is generated so as to correspond to the elemental width time, the characteristic thereof is set to one such that the band width is proportional to a reciprocal of a time period representing width length data of the white region and the black region.

[0268]

(Additional Note 30) A method of reading information according to Additional Note 24, characterized in that when the timing point is specified, calculation is made to determine a phase of the periodic signal corresponding to the elemental time width of the width length data, and the timing point is specified based on the calculated phase information.

(Additional Note 31) A method of reading information according to Additional Note 30, characterized in that when the calculation is made to determine the phase of the periodic signal corresponding to the elemental time width of the width length data, the periodic signal corresponding to the elemental time width of the width length data is formed into a vector, and calculation is made to determine the phase thereof while the

signal formed into the vector is handled as an input signal.

[0269]

(Additional Note 32) A method of reading information according to Additional Note 31, characterized in that when the periodic signal corresponding to the elemental time width of the width length data is formed into a vector, the periodic signal corresponding to the elemental width time of the width length data is set to a real number part and a number deriving from Hilbert transform applied to the periodic signal corresponding to the elemental width time of the width length data is set to an imaginary number part.

(Additional Note 33) A method of reading information according to Additional Note 30, characterized in that time information regarding a point at which the phase of the periodic signal becomes zero degree is extracted, and this extracted time information is specified as a timing point.

[0270]

(Additional Note 34) A method of reading information according to Additional Note 33, characterized in that when a signal containing the binary digit information is acquired, the signal is acquired as a digital signal created by sampling operation at a predetermined sampling interval, search is made on the result of calculation effected on the phase of the periodic signal for finding a couple of signal points which are adjacent to each other and at which the sign of the signal is changed, and a signal point closer to a zero-degree phase is specified as the timing point.

[0271]

(Additional Note 35) A method of reading information according to Additional Note 34, characterized in that time error of the specified timing point with respect to the point at which the phase of the periodic signal becomes zero degree is extracted, and the signal having undergone the differentiation processing is delayed by an amount corresponding to the time error at every timing point at which the time error is extracted.

(Additional Note 36) A method of reading information according to Additional Note 35, characterized in that when the signal having undergone the differentiation processing is delayed by an amount corresponding to the time error at every timing point at which the time error is extracted, a filter processing is effected in a convolution manner in such a way that the gain thereof is set to one up to the maximum input signal band in which the signal can be acquired as the intensity variation state detecting signal, the gain thereof is gradually attenuated as the frequency of the processing is remote from the band, and that the signal is delayed by an amount proportional to the extracted time error.

[0272]

(Additional Note 37) A method of reading information according to Additional Note 36, characterized in that when coefficients for the filter processing are determined, a filter characteristic function is determined in such a way that the gain thereof is set to one up to the maximum input signal band in which the signal can be acquired as the intensity variation

state detecting signal and the gain thereof is gradually attenuated as the frequency of the processing is remote from the band, a function for delaying the signal by an amount proportional to the amount of extracted time error is created, this function is added with the filter characteristic function, and that the result of addition is subjected to an inverse Fourier transform.

[0273]

(Additional Note 38) A method of reading information according to Additional Note 36, characterized in that when coefficients for the filter processing are determined, sets of filter coefficients corresponding to a plurality of delay filter characteristics are prepared in advance so as to handle various amounts of the extracted time errors, it is determined which of the filter processing characteristic of the plurality of filter characteristics is to be applied depending on the amount of the extracted time error, and a set of filter coefficients is selected so that the set of filter coefficients provides a filter characteristic capable of handling the result of determination.

[0274]

(Additional Note 39) A method of reading information according to Additional Note 36, characterized in that when coefficients for the filter processing are determined, an impulse response data is obtained based on the filter characteristic function such that the gain thereof is set to one up to the maximum input signal band in which the signal can be acquired as the

intensity variation state detecting signal and the gain thereof is gradually attenuated as the frequency of the processing is remote from the band, and the impulse response data is subjected to an interpolation processing depending on the amount of the extracted time error, whereby the filter coefficients are determined.

[0275]

(Additional Note 40) A method of reading information according to Additional Note 39, characterized in that when the impulse response data is subjected to an interpolation processing, a first-order approximation is employed.

(Additional Note 41) A method of reading information according to Additional Note 24, characterized in that when the amplitude values extracted at every timing point are converted into a tri-state value digital signal, the amplitude values of the extracted signal are subjected to a determination/output process for classifying the values into tri-state data composed of digits of "+1", "0", and "-1", and

on the basis of the tri-state value data, each digit is associated with an edge existing point in such a manner that a signal point containing a data piece of "+1" corresponds to one of the edge existing points of the white region and the black region, a signal point containing a data piece of "-1" corresponds to the other of the edge existing points of the white region and the black region, and a signal point containing a data piece of "0" corresponds to a point at which no edge is present, whereby the integer number ratio between the width length data of each

information element pair is read.

[0276]

(Additional Note 42) A method of reading information according to Additional Note 41, characterized in that when the extracted amplitude values are subjected to the determination/output process as a tri-state value data, a least square method is applied to correct distortions in the amplitude and phase contained in the width length data signal.

(Additional Note 43) A method of reading information according to Additional Note 41, characterized in that when the amplitude values of the extracted signal are subjected to the determination/output process to generate data composed of "+1" or "-1", determination is made in such a way that, of the amplitude values of signal points having the same sign and adjacent to each other, the largest point is associated with "+1", the smallest point is associated with "-1", and amplitude values other than those associated with "+1" or "-1" are associated with "0".

[0277]

(Additional Note 44) A method of reading information from a medium having a mark recorded thereon, the mark representing a data group composed of a predetermined number of information element pairs each composed of a white region and a black region each having a width length and disposed alternately on the mark for representing the data group, the method of reading information achieving information reading by acquiring the data group information as an integer number ratio between the width

length data of each information element pair, the method characterized by comprising steps of:

scanning the mark with a ray of light running at a predetermined velocity;

receiving a ray of light coming from the outside and outputting an intensity variation detecting signal representing the intensity variation of the received ray of light; and

determining whether or not the received ray of light is one having scanned the mark and reflected therefrom based on the intensity variation detecting signal; wherein

in accordance with the result of determination, a signal reflected on the mark coming from an intensity variation detecting width information medium is acquired as a signal for reading information of the data group as an integer number ratio between the width length data of each information element pair, while any component of the intensity variation state detecting signal other than the component of the ray of light reflected on the mark is excluded from an object of the signal to be acquired.

[0278]

(Additional Note 45) A method of reading information according to Additional Note 44, characterized in that when examination is made to determine whether the received ray of light is one having scanned the mark and reflected therefrom or not, the intensity variation optical signal is subjected to a differentiation processing, the differentiated signal having undergone the differentiating processing is squared, and moving average is calculated on the squared differentiated signal, and

an intensity variation state detecting signal part is cut out from the ray of light reflected on the mark based on a value obtained by the method of moving average, whereby the cut-out signal part is acquired as a acquired signal.

[0279]

(Additional Note 46) A method of reading information according to Additional Note 44, characterized by a procedure to be done when examination is made to determine whether the received ray of light is one having scanned the mark and reflected therefrom or not, the procedure comprising steps of:

subjecting the intensity variation optical signal to a differentiation processing;

squaring the differentiated signal;

calculating moving average on the squared differentiated signal;

examining whether the extracted maximum value of the moving averages exceeds a first threshold value or not to determine a status of validity for the squared differentiated signal in such a manner that, if it is determined that the maximum value exceeds the first threshold value the differentiated squared signal is regarded as a valid signal while if is determined that the maximum value does not exceed the first threshold value the differentiated squared signal is regarded as an invalid signal;

effecting an averaging processing on the differentiated squared signal in a period in which the differentiated squared signal is valid, thereby obtaining an averaged value thereof;

extracting the maximum value from the differentiated

squared signal in a period in which the differentiated squared signal is valid;

calculating the difference between the averaged value and the maximum value of the differentiated squared signal in a period in which the differentiated squared signal is valid;

comparing the difference with a predetermined second threshold value to determine a way of acquiring the intensity variation state detecting signal in such a manner that, if the difference is smaller than the second threshold value a portion of the intensity variation state detecting signal corresponding to the aforesaid period is cut out so that only the cut-out signal portion is acquired as an acquired signal while if the difference is larger than the second threshold value the portion of the intensity variation state detecting signal corresponding to the aforesaid period is excluded as an object to be acquired as the acquired signal.

[0280]

(Additional Note 47) A method of reading information characterized by comprising a step of acquiring a value from a signal containing binary digit information having a predetermined information length and deriving from information elements arrayed one-dimensionally on a medium at every equal time interval, wherein

when an elemental unit length of the information length of the binary digit information is extracted from the acquired signal, the portion of the signal for extracting the state of the binary digit information from the medium information has

a band narrower than that of the characteristic for differentiation based on the equal time interval.

[0281]

(Additional Note 48) A method of reading information according to Additional Note 47, characterized in that the elemental unit length information is extracted as elemental frequency information corresponding to the elemental unit length, the read signal is subjected to band-limitation processing based on the extracted elemental frequency information, and after differentiating processing is effected thereon, a ratio of binary digit information to the information length is read.

(Additional Note 49) A read signal processing unit comprising means for acquiring a signal containing binary digit information having a predetermined information length and deriving from information elements arrayed one-dimensionally on a medium and extracting an elemental frequency corresponding to the elemental unit length of the information length of the binary digit information from the acquired signal, and

means for effecting a band limiting processing on the acquired signal based on the extracted elemental frequency signal and thereafter extracting boundary information of the binary digit information.

[0282]

(Additional Note 50) A read signal processing unit comprising means for acquiring a signal containing binary digit information having a predetermined information length and deriving from information elements arrayed one-dimensionally

on a medium and extracting an elemental frequency corresponding to the elemental unit length of the information length of the binary digit information from the acquired signal, and

means for effecting a band limiting processing on the acquired signal based on the extracted elemental frequency signal and thereafter extracting a ratio of the information length of the binary digit information.

[0283]

[Effect of the Invention]

As described above in detail, according to the method of reading information as claimed in Claims 1 to 3 of the present invention, information concerning the elemental unit length of the information length of the binary digit information can be extracted from the acquired signal, and the ratio of the information length of the binary digit information can be read based on the extracted elemental unit length information. Therefore, it becomes possible to suppress a size of hardware and a price thereof and to improve the S/N ratio of the reading signal and reading resolution. Moreover, even if the depth of field for reading is enlarged or a concave/convex portion or a blurred portion is left on the reading face, reading precision can be improved.

[0284]

Further, according to the method of reading information as claimed in Claim 4 of the present invention, when the elemental unit length of the information length of the binary digit information is extracted from the acquired signal, the signal

portion in which the state of the binary digit information is extracted from the medium information can take a band narrower than that of the characteristic for differentiation of the equal time interval. Therefore, when at least the information length of the binary digit information is read, it becomes possible to carry out differentiation processing for limiting the band to the optimum one.

[0285]

Furthermore, according to the read signal processing unit as claimed in Claim 5 of the present invention, the arrangement thereof includes the means for extracting the elemental frequency and the means for extracting the boundary information of the binary digit information. Therefore, at least the process of band limiting and the tri-state value generation effected on the acquired signal can be independently shared by a group of function units which are provided separately with respect to another function unit. Therefore, the function units serving as the read signal processing unit can be incorporated into another information processing system for the processing or the like. Thus, it becomes possible to diversify the variation of the system arrangement while keeping the general-use nature of the system.

[0286]

In addition, according to the information reading apparatus as claimed in Claims 6 and 7 of the present invention, the band limiting unit limits the frequency band of the acquired signal and the ratio of the information length of the binary

digit information can be read from the acquired signal in the optimum band. Therefore, the reading apparatus is not requested to have a circuit capable of handling a wide band characteristic on the receiving side thereof. Moreover, if the signal-to-noise ratio (S/N) is improved, the reading area can be enlarged, the reading resolution can be improved and the reading accuracy can be improved even when the medium itself contains a cause of reading noise. Furthermore, the reading apparatus can be free from being equipped with a clock operated at a high rate in order for measuring the elemental unit length of the information length of the binary digit information. Therefore, even if the sampling accuracy is lowered, the reading accuracy of the binary digit information can be kept high, and cost performance in hardware constituting the apparatus will be improved while the performance of the apparatus is enhanced.

[0287]

Furthermore, according to the method of acquiring a signal for use in the information reading apparatus as claimed in Claim 8 of the present invention, when the signal acquiring section acquires a signal, the section is supplied with a signal additionally containing a signal component other than one deriving from the medium having the binary digit information recorded thereon. Of the signals supplied thereto, a portion of the signal deriving from the medium having the binary digit information recorded thereon is subjected to the amplitude averaging calculation processing to carry out determination. Then, the portion of the signal deriving from the medium is cut

out in accordance with the result of determination, and the cut-out portion is acquired as a signal containing the binary digit information. Accordingly, a signal portion other than one necessary for acquiring the binary digit information can be excluded from a target of subsequent signal processing in the information reading apparatus, and hence the processing load imposed on the apparatus can be decreased.

[0288]

Furthermore, according to the method of processing band limitation for use in the information reading apparatus as claimed in Claim 9 of the present invention, as a preprocessing for reading the ratio data of the information length of the binary digit information, the elemental frequency corresponding to the elemental unit length is extracted from the acquired signal, and the frequency band of the acquired signal can be limited based on the extracted elemental frequency. Therefore, information concerning the elemental unit length of the information length of the binary digit can be extracted from the acquired signal, and on the basis of the extracted elemental unit length information, the ratio of the information length of the binary digit information can be read. Therefore, it becomes possible to suppress a size of hardware and a price thereof and to improve the S/N ratio of the reading signal and reading resolution. Moreover, even if the depth of field for reading is enlarged or a concave/convex portion or a blurred portion is left on the reading face, reading precision can be improved.

[0289]

Furthermore, according to the present invention as claimed in Claim 10, as a preprocessing for reading the ratio of the information length of the binary digit information, extraction is made on the timing point synchronous with the acquired signal and having the elemental frequency based on the acquired signal and the elemental frequency information, extraction is also made on the amplitude value of the signal supplied from the band limiting unit in accordance with the extracted timing point, and the amplitude value can be led as the tri-state value data in accordance with the extracted timing point. Therefore, it becomes possible to improve the resolution in reading information together with the S/N ratio of the read signal. Furthermore, even if the depth of field for reading is enlarged or a concave/convex portions or a blurred portion are left on the reading face, the reading accuracy can be improved. In particular, if the signal acquisition is made on the photoelectric converted signal deriving from the reflected ray of light of a Gaussian beam, it becomes possible to correct distortion caused by delay of a group of circuits together with the distortion caused by intersymbol interference due to the Gaussian beam or the like. Therefore, the above-described reading resolution can be remarkably improved. Furthermore, since the module length is counted, it becomes unnecessary to carry out high rate sampling on the acquired signal, with the result that the cost for constructing the apparatus can be remarkably reduced.

[Brief Description of the Drawings]

[FIG. 1]

A block diagram showing a bar code reading apparatus according to the present embodiment.

[FIG. 2]

A diagram for explaining a transversal filter employed in the bar code reading apparatus of the present embodiment.

[FIG. 3]

A diagram showing the transversal filter employed in the bar code reading apparatus of the present embodiment.

[FIG. 4]

A set of diagrams (a) to (d) each for explaining the bar code reading apparatus according to one embodiment of the present invention.

[FIG. 5]

A block diagram showing a cut-out unit of the present embodiment.

[FIG. 6]

A set of diagrams (a) to (c) each for explaining the cut-out unit of the present embodiment.

[FIG. 7]

A block diagram for explaining an operation of the cut-out unit of the present embodiment.

[FIG. 8]

A block diagram showing a modification of the cut-out unit of the present embodiment.

[FIG. 9]

A set of diagrams (a) to (c) each for explaining the

modification of the cut-out unit of the present embodiment.

[FIG. 10]

A diagram for explaining an adaptive-type band limiting differentiation introduced into the present embodiment.

[FIG. 11]

A diagram for explaining an adaptive-type band limiting differentiation introduced into the present embodiment.

[FIG. 12]

A diagram for explaining an adaptive-type band limiting differentiation introduced into the present embodiment.

[FIG. 13]

A diagram for explaining an adaptive-type band limiting differentiation introduced into the present embodiment.

[FIG. 14]

A diagram for explaining an adaptive-type band limiting differentiation introduced into the present embodiment.

[FIG. 15]

A diagram for explaining an adaptive-type band limiting differentiation introduced into the present embodiment.

[FIG. 16]

A diagram for explaining an adaptive-type band limiting differentiation introduced into the present embodiment.

[FIG. 17]

A diagram for explaining an adaptive-type band limiting differentiation introduced into the present embodiment.

[FIG. 18]

A diagram for explaining an adaptive-type band limiting

differentiation introduced into the present embodiment.

[FIG. 19]

A diagram for explaining an adaptive-type band limiting differentiation introduced into the present embodiment.

[FIG. 20]

A diagram for explaining an adaptive-type band limiting differentiation introduced into the present embodiment.

[FIG. 21]

A diagram for explaining an adaptive-type band limiting differentiation introduced into the present embodiment.

[FIG. 22]

A block diagram showing an adaptive-type band limiting differentiating unit of the present embodiment.

[FIG. 23]

A diagram for explaining an operation of the adaptive-type band limiting differentiating unit of the present embodiment.

[FIG. 24]

A block diagram showing a main portion of a first modification of the adaptive-type band limiting differentiating unit of the present embodiment.

[FIG. 25]

A diagram for explaining an operation of the first modification of the adaptive-type band limiting differentiating unit of the present embodiment.

[FIG. 26]

A diagram for explaining an operation of the first modification of the adaptive-type band limiting differentiating

unit of the present embodiment.

[FIG. 27]

A flowchart for explaining the operation of a main portion of the adaptive-type band limiting differentiating unit of the present embodiment.

[FIG. 28]

A diagram for explaining the operation of the main portion of the adaptive-type band limiting differentiating unit of the present embodiment.

[FIG. 29]

A block diagram showing an every module point amplitude extracting unit of the present embodiment.

[FIG. 30]

A diagram for explaining an operation of the every module point amplitude extracting unit of the present embodiment.

[FIG. 31]

A set of diagrams (a) to (c) each for explaining the operation of the every module point amplitude extracting unit of the present embodiment.

[FIG. 32]

A diagram for explaining the operation of the every module point amplitude extracting unit of the present embodiment.

[FIG. 33]

A diagram for explaining the operation of the every module point amplitude extracting unit of the present embodiment.

[FIG. 34]

A diagram for explaining the operation of the every module

point amplitude extracting unit of the present embodiment.

[FIG. 35]

A block diagram showing a main portion of the every module point amplitude extracting unit of the present embodiment.

[FIG. 36]

A diagram for explaining the operation of the every module point amplitude extracting unit of the present embodiment.

[FIG. 37]

A diagram for explaining the operation of the every module point amplitude extracting unit of the present embodiment.

[FIG. 38]

A set of diagrams (a) to (c) each for explaining the operation of the every module point amplitude extracting unit of the present embodiment.

[FIG. 39]

A block diagram showing a main portion of the every module point amplitude extracting unit of the present embodiment.

[FIG. 40]

A diagram for explaining the operation of the every module point amplitude extracting unit of the present embodiment.

[FIG. 41]

A diagram for explaining the operation of the every module point amplitude extracting unit of the present embodiment.

[FIG. 42]

A block diagram for showing a main portion of a modification of the every module point amplitude extracting unit of the present embodiment.

[FIG. 43]

A block diagram for showing a main portion of a modification of the every module point amplitude extracting unit of the present embodiment.

[FIG. 44]

A diagram for explaining the operation of the modification of the every module point amplitude extracting unit of the present embodiment.

[FIG. 45]

A diagram for explaining the operation of the modification of the every module point amplitude extracting unit of the present embodiment.

[FIG. 46]

A diagram for explaining the operation of the modification of the every module point amplitude extracting unit of the present embodiment.

[FIG. 47]

A block diagram showing a main portion of the every module point amplitude extracting unit of the present embodiment.

[FIG. 48]

A block diagram showing in detail an arrangement of the main portion of the every module point amplitude extracting unit of the present embodiment.

[FIG. 49]

A diagram for explaining the operation of the every module point amplitude extracting unit of the present embodiment.

[FIG. 50]

A diagram for explaining the operation of the every module point amplitude extracting unit of the present embodiment.

[FIG. 51]

A set of diagrams (a) and (b) each for explaining the operation of the every module point amplitude extracting unit of the present embodiment.

[FIG. 52]

A diagram for explaining an advantage of the bar code reading apparatus of the present embodiment.

[FIG. 53]

A diagram for explaining an advantage of the bar code reading apparatus of the present embodiment.

[FIG. 54]

A set of diagrams (a) to (e) each for explaining an advantage of the bar code reading apparatus of the present embodiment.

[FIG. 55]

A block diagram showing another embodiment of the present invention.

[FIG. 56]

A block diagram showing another embodiment of the present invention.

[FIG. 57]

A diagram showing an outward appearance of the bar code reading apparatus.

[FIG. 58]

A block diagram showing a conventional bar code reading apparatus.

[FIG. 59]

A block diagram showing a conventional bar code reading apparatus.

[FIG. 60]

A diagram for explaining an operation of the conventional bar code reading apparatus.

[FIG. 61]

A diagram for explaining an operation of the conventional bar code reading apparatus.

[FIG. 62]

A diagram for explaining an operation of the conventional bar code reading apparatus.

[Explanation of reference numerals]

1 the bar code

1A the optical scanning section

1B the analog processing section

1C the reading processing section

1a-1 the LD

1a-2 the polygon mirror

1b the light receiving unit

1c the amplifying unit

1d the AD converter

1e the cut-out unit

1f the adaptive type band-limiting differentiating unit

1g the module frequency extracting unit

1h the band limiting differentiation processing unit

1h' the decimation processing unit

1i the every module point amplitude extracting unit
1j the module timing signal extracting unit
1k the amplitude extracting unit
1l the tri-state value generating unit
1m the module number calculating unit
1n the character arrangement checking unit

[Name of Document] ABSTRACT

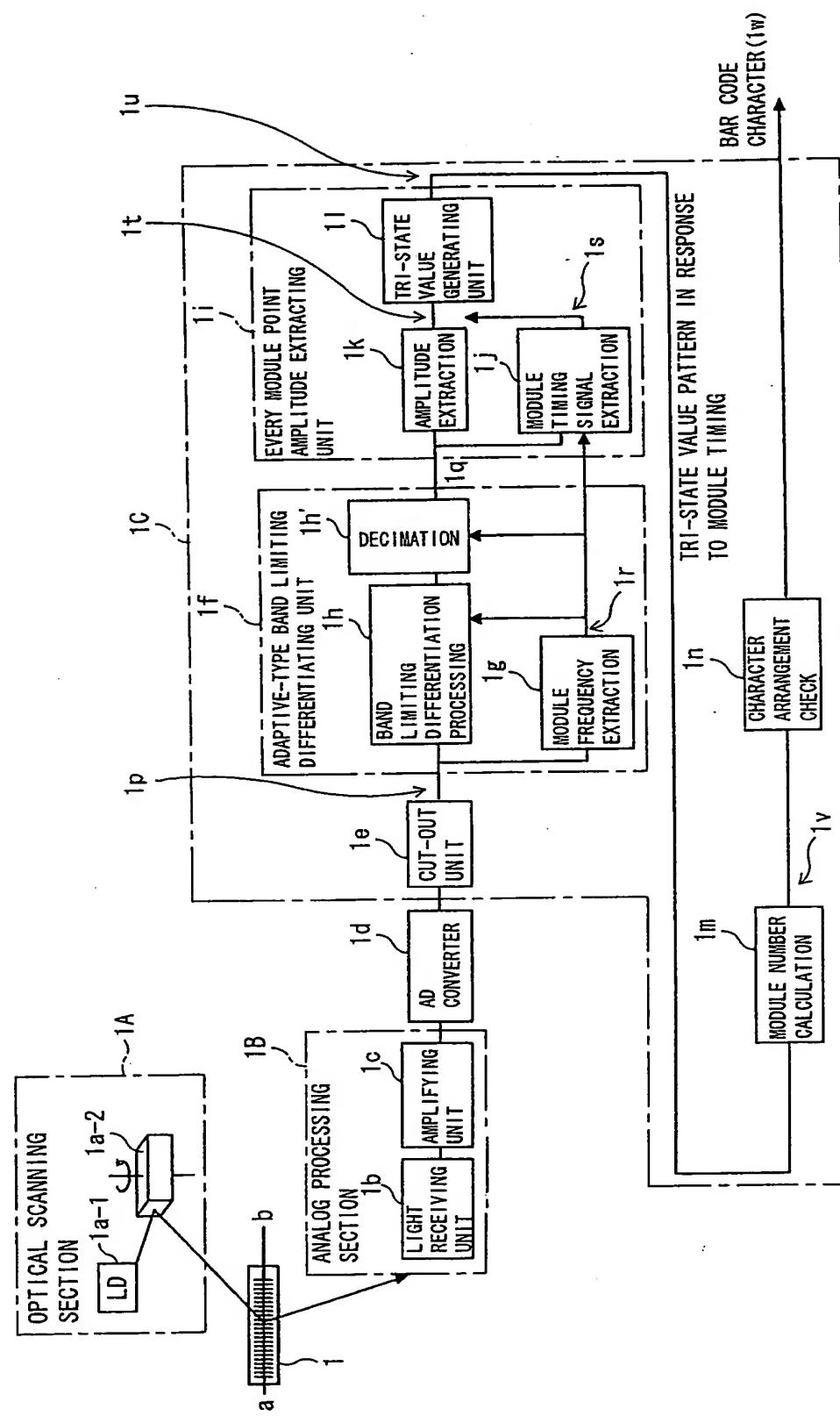
[Summary]

[Problems] There is provided a method of reading information which makes it possible to suppress the size of hardware and a price thereof and to improve an S/N ratio of a reading signal and reading resolution, wherein even if depth of field for reading is enlarged or a concave/convex portion or a blurred portion is left on the reading face, reading precision can be improved.

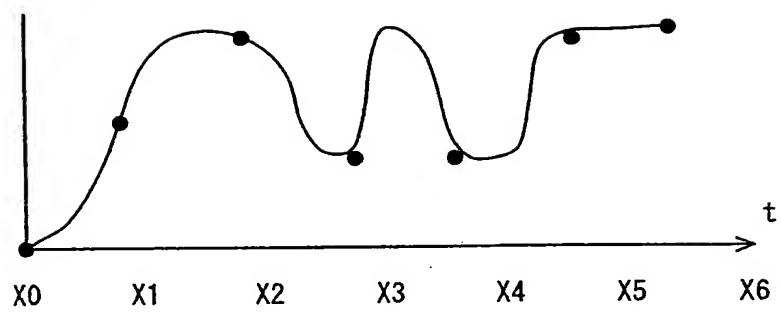
[Solving means] The method includes steps of acquiring from a medium 1, a signal containing binary digit information having a predetermined information length and a one-dimensional arrangement, extracting information concerning an elemental unit length of the information length of the binary digit information from the acquired signal, and reading a ratio of the binary digit information to the information length based on the extracted elemental unit length information.

[Selected Diagram] FIG. 1

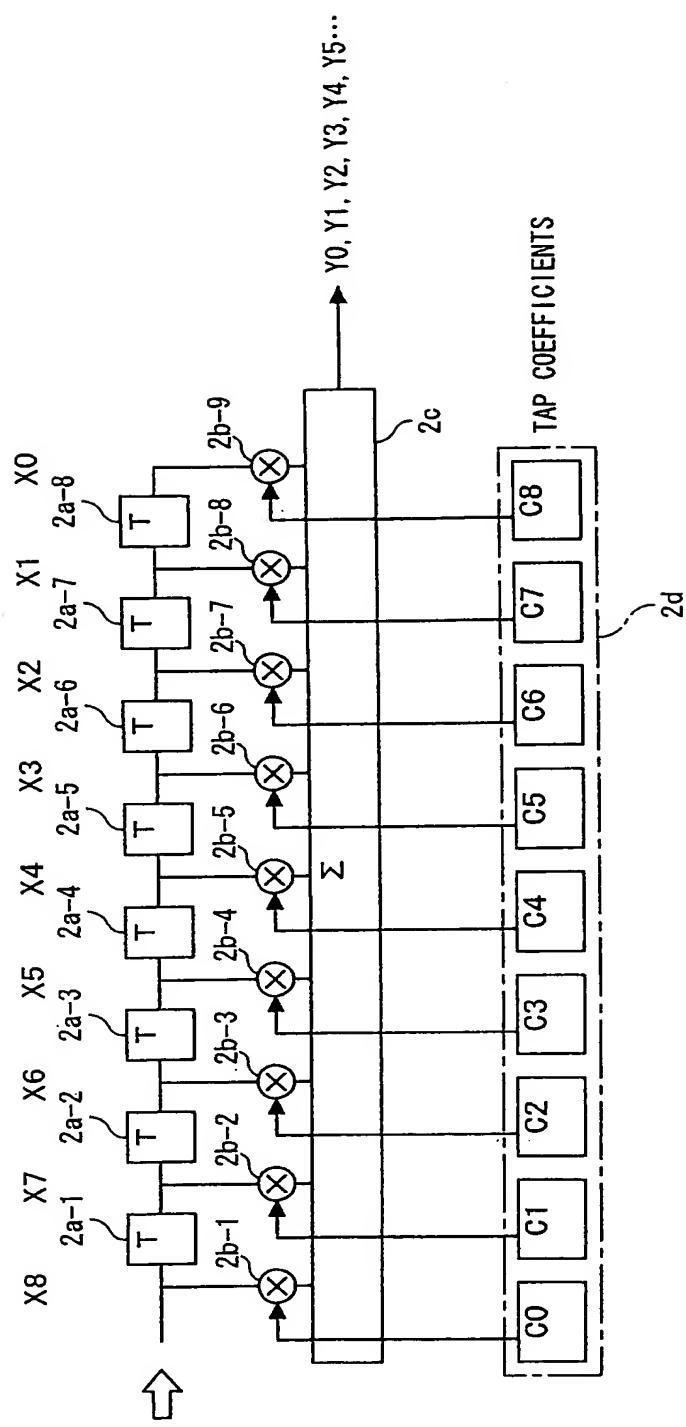
[FIG.1]



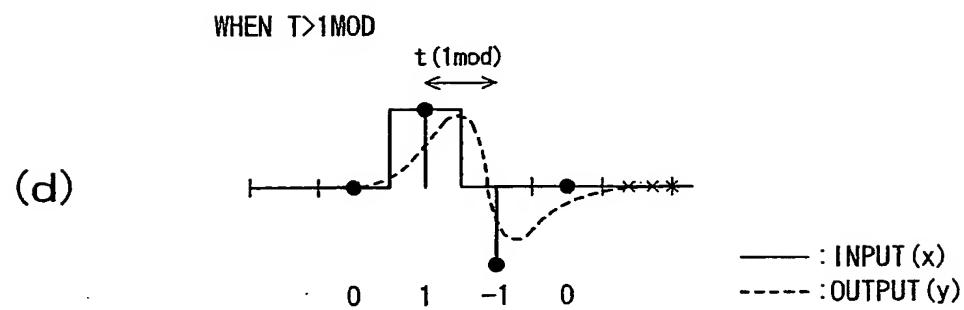
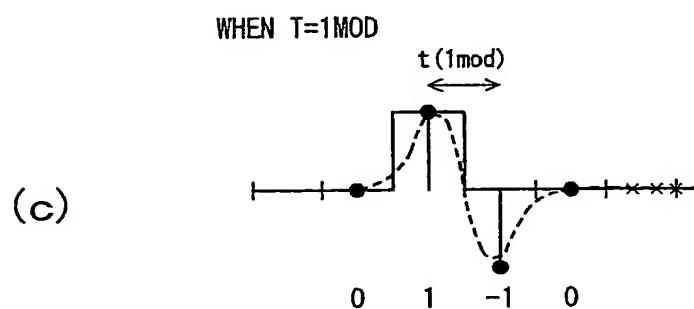
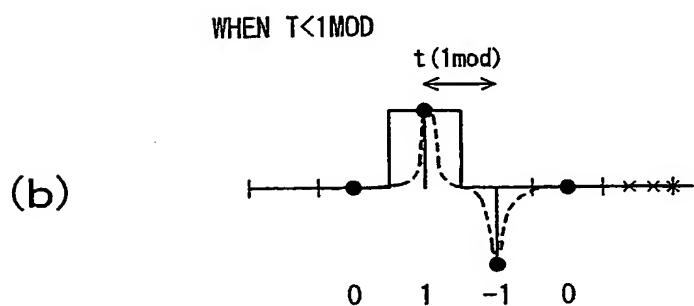
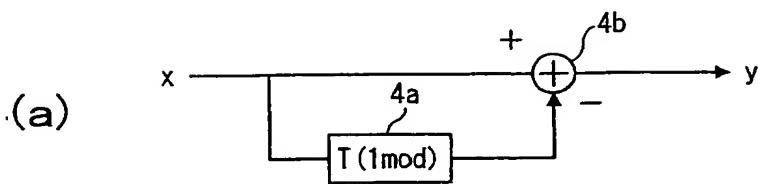
[FIG.2]



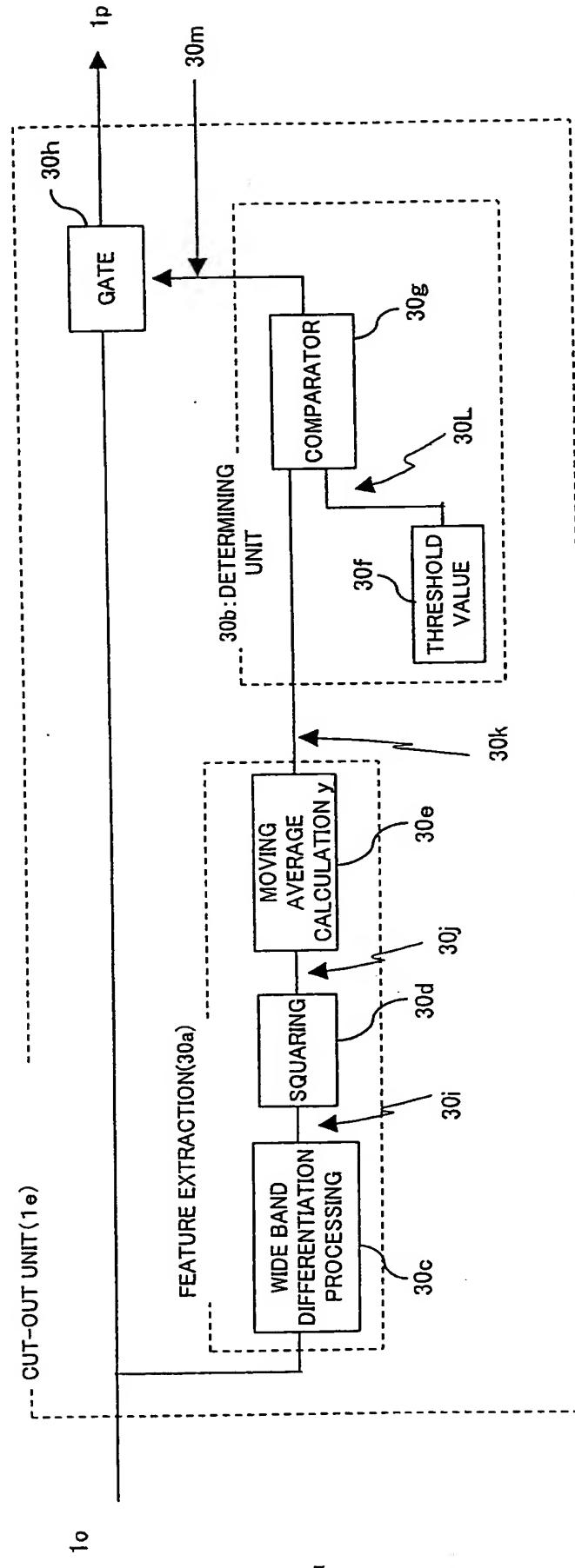
[FIG.3]



[FIG.4]

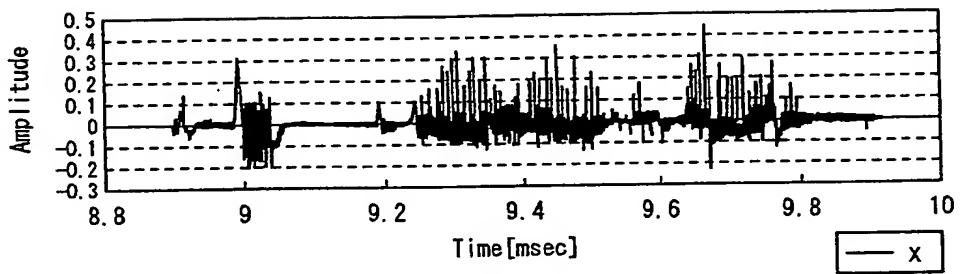


[FIG.5]

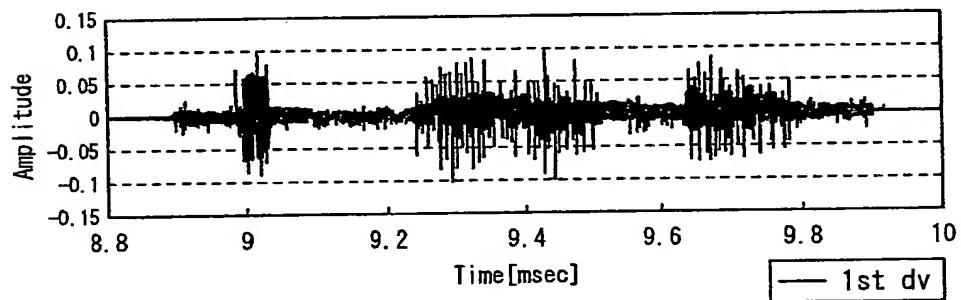


[FIG. 6]

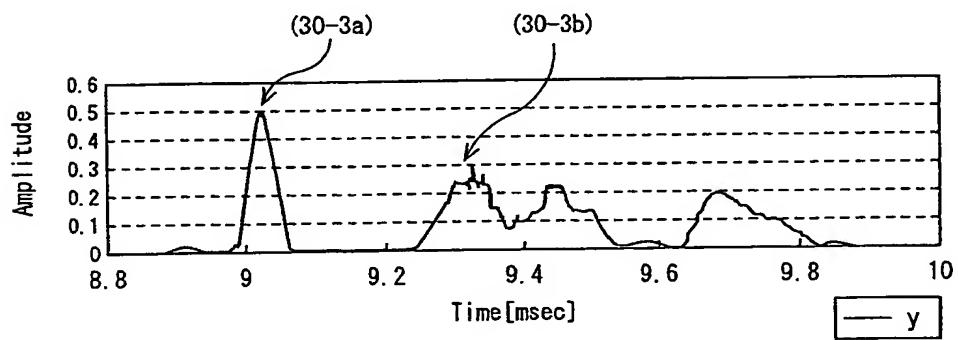
(a)



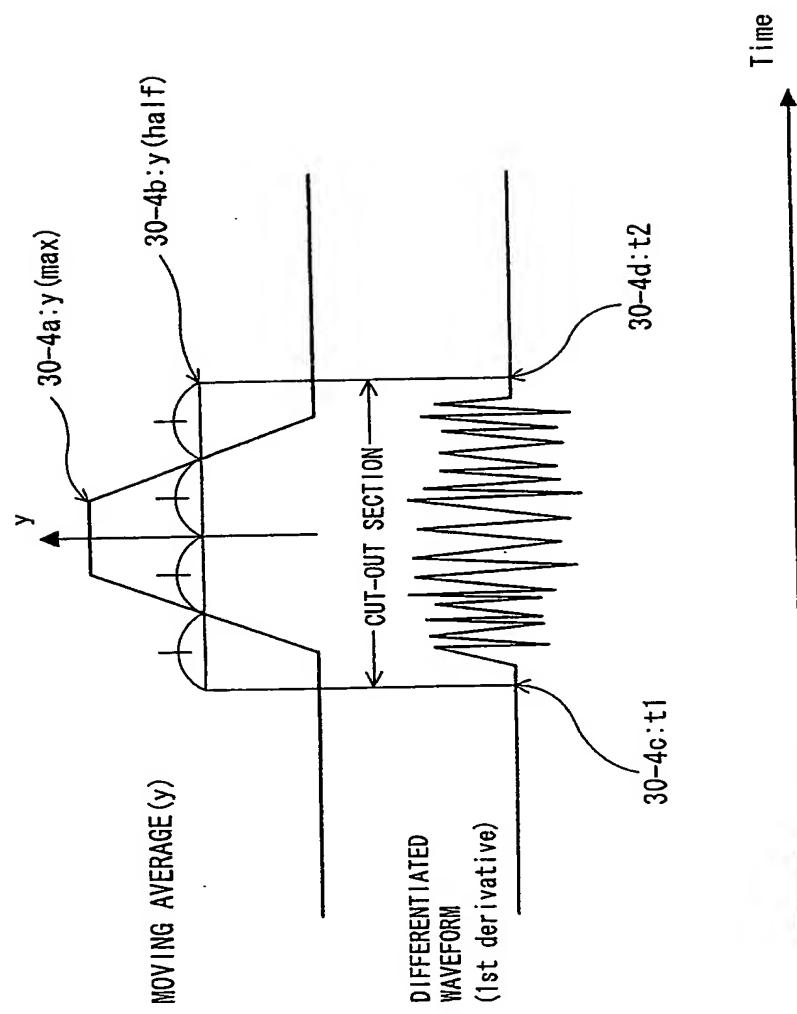
(b)



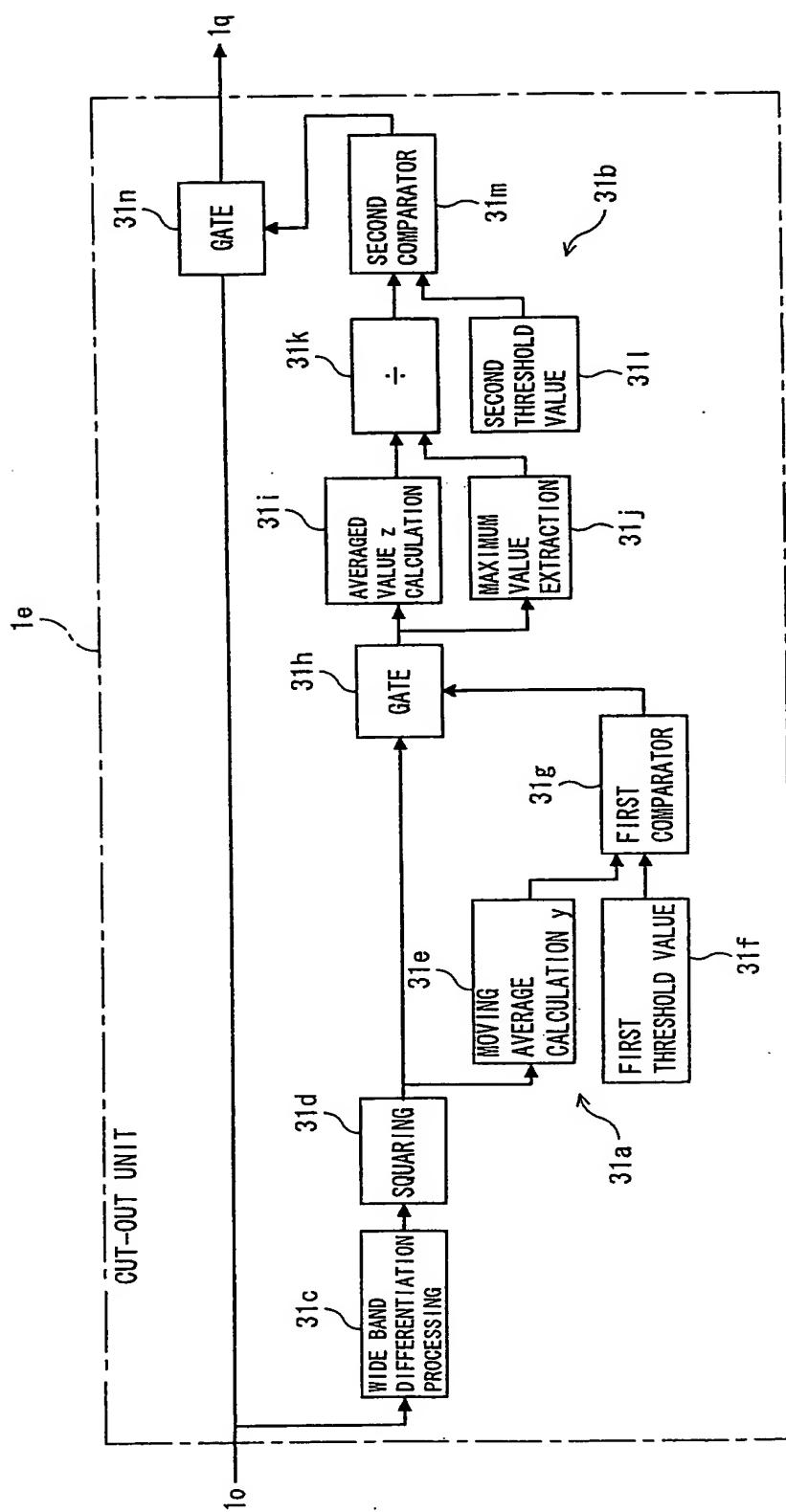
(c)



[FIG. 7]

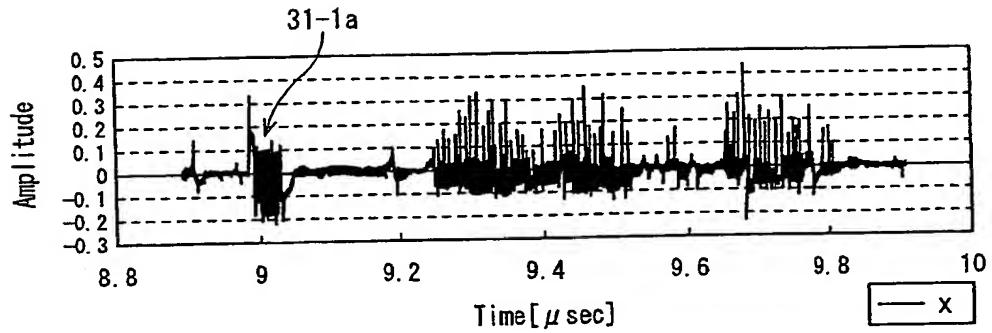


[FIG.8]

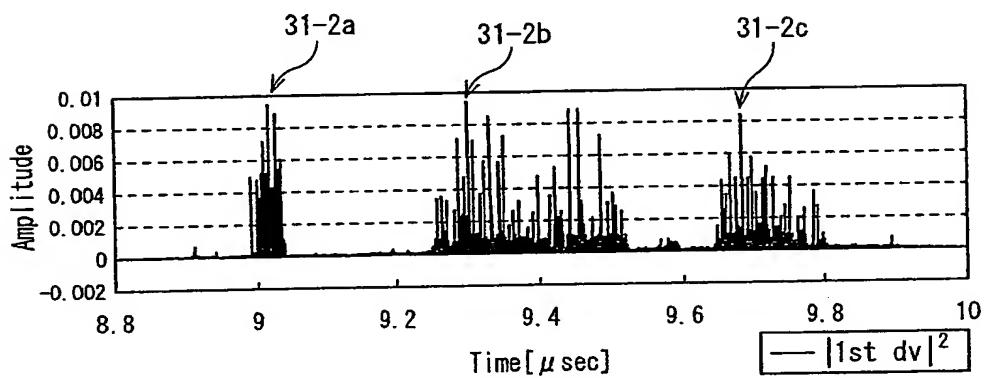


[FIG.9]

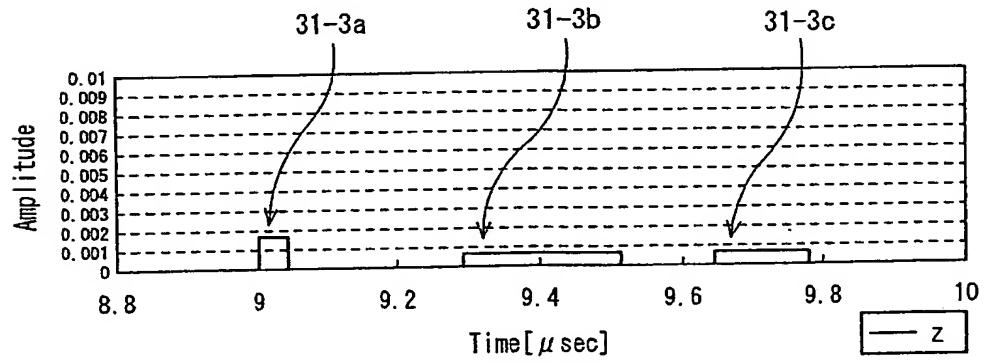
(a)



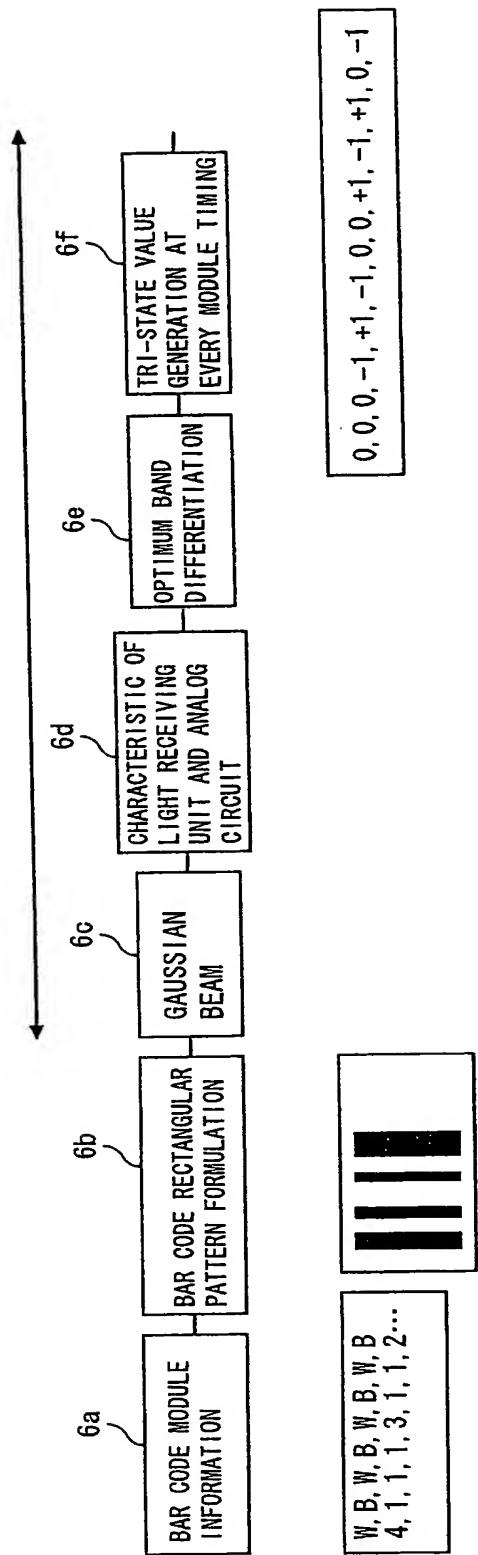
(b)



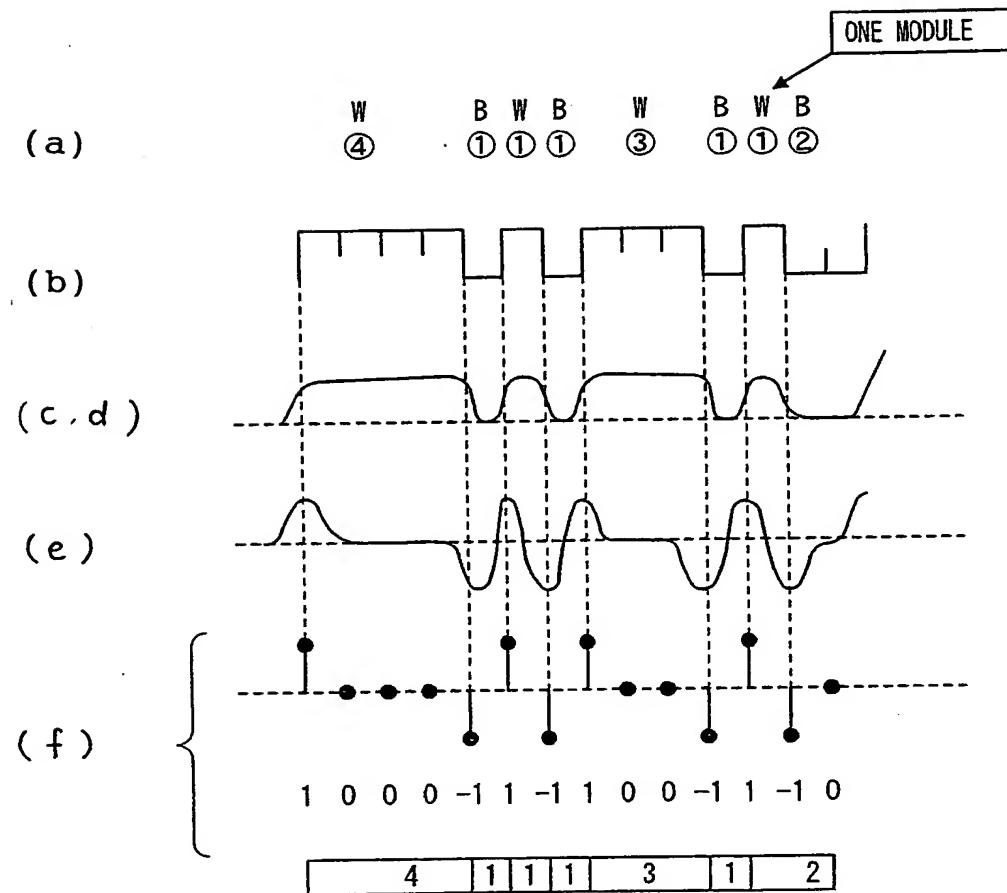
(c)



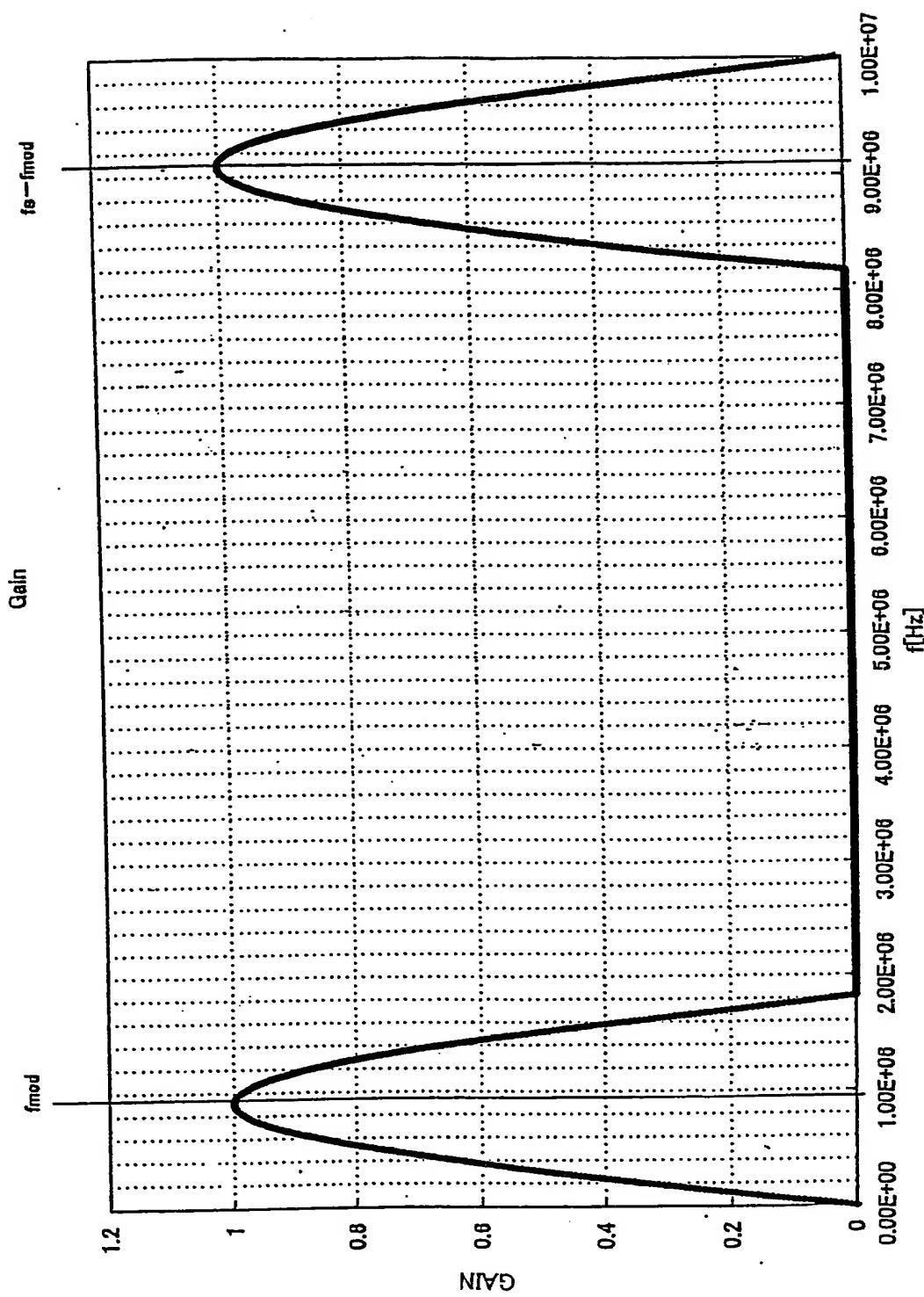
[FIG.10]



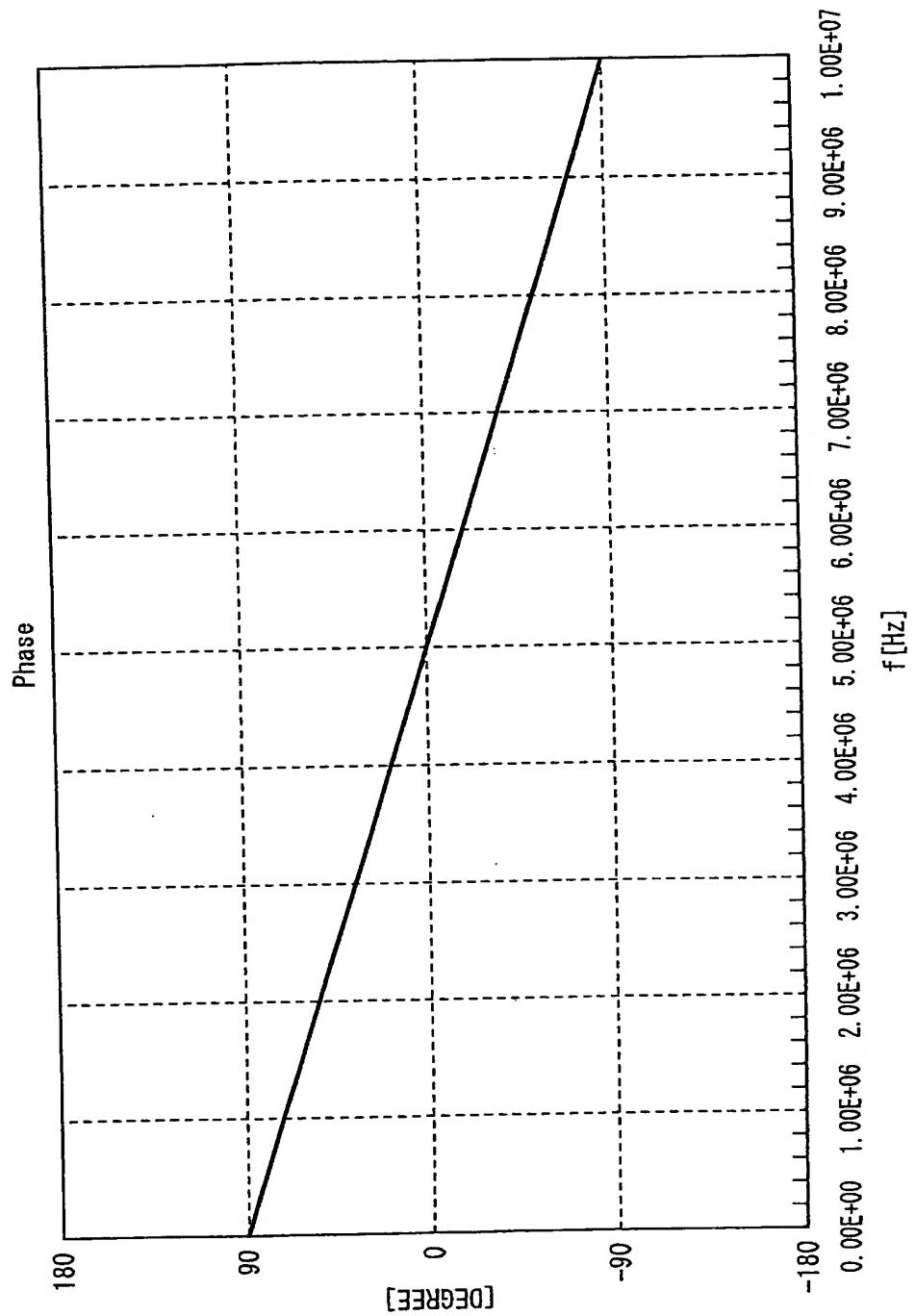
[FIG.11]



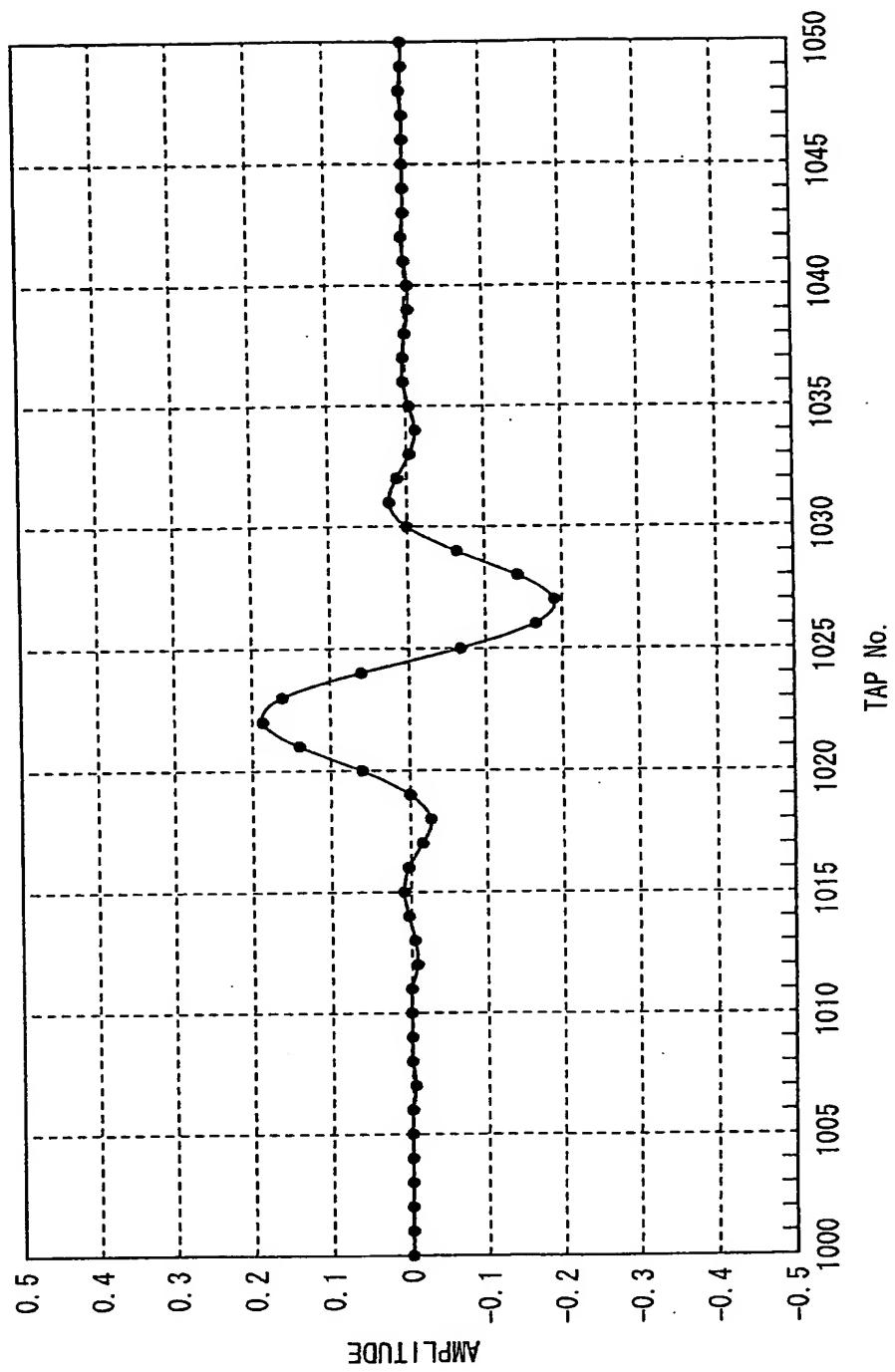
[FIG.12]



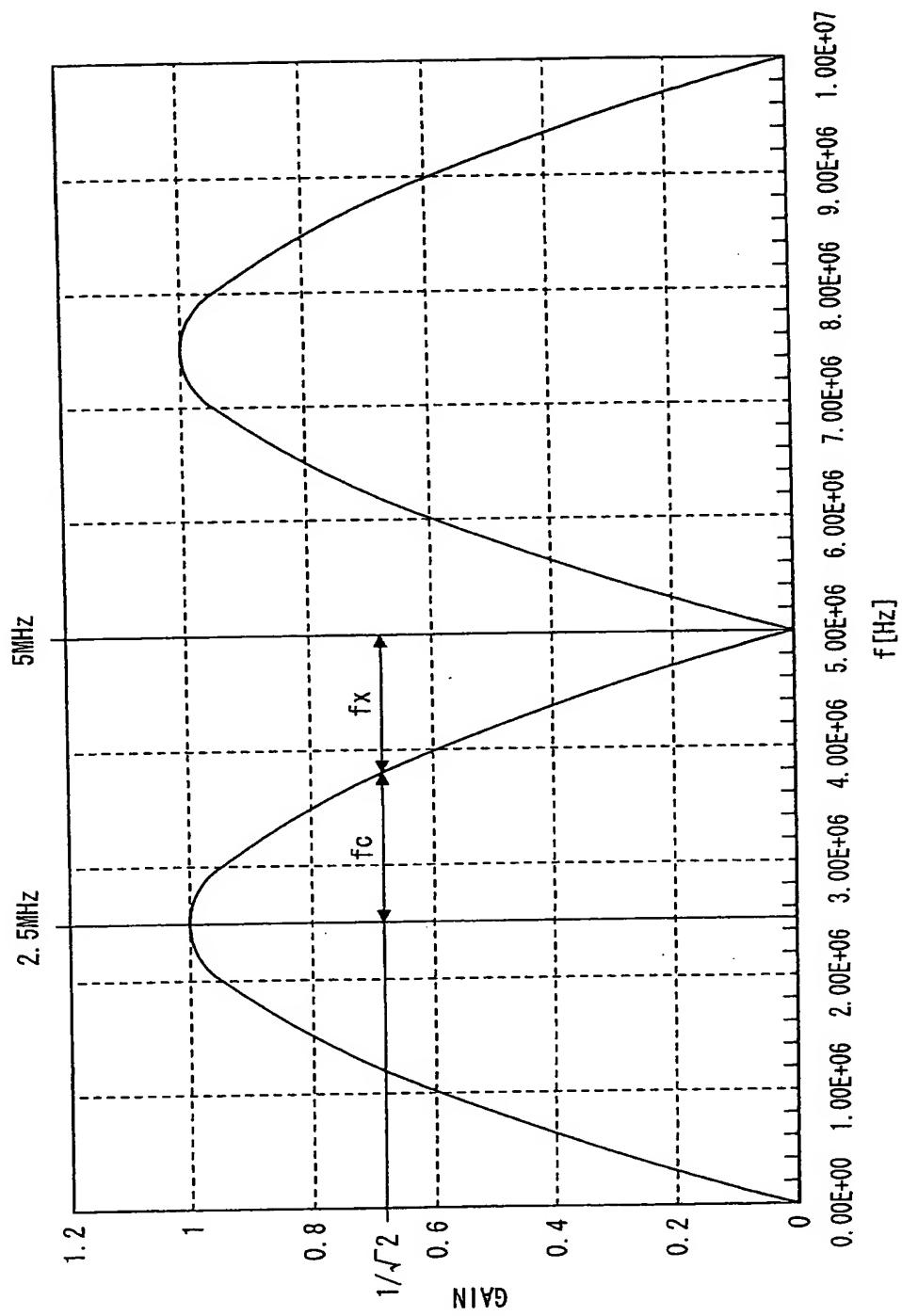
[FIG.13]



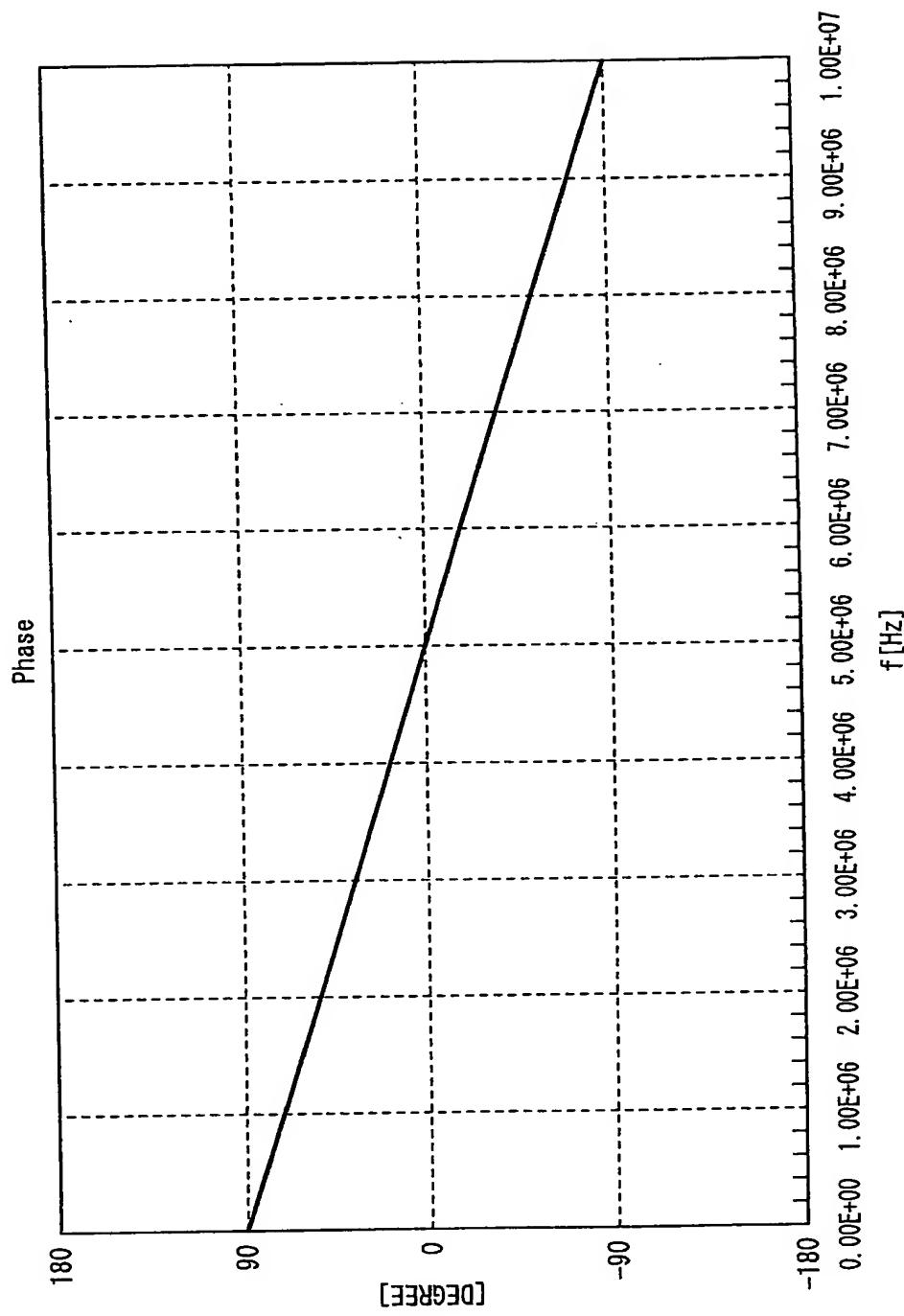
[FIG. 14]



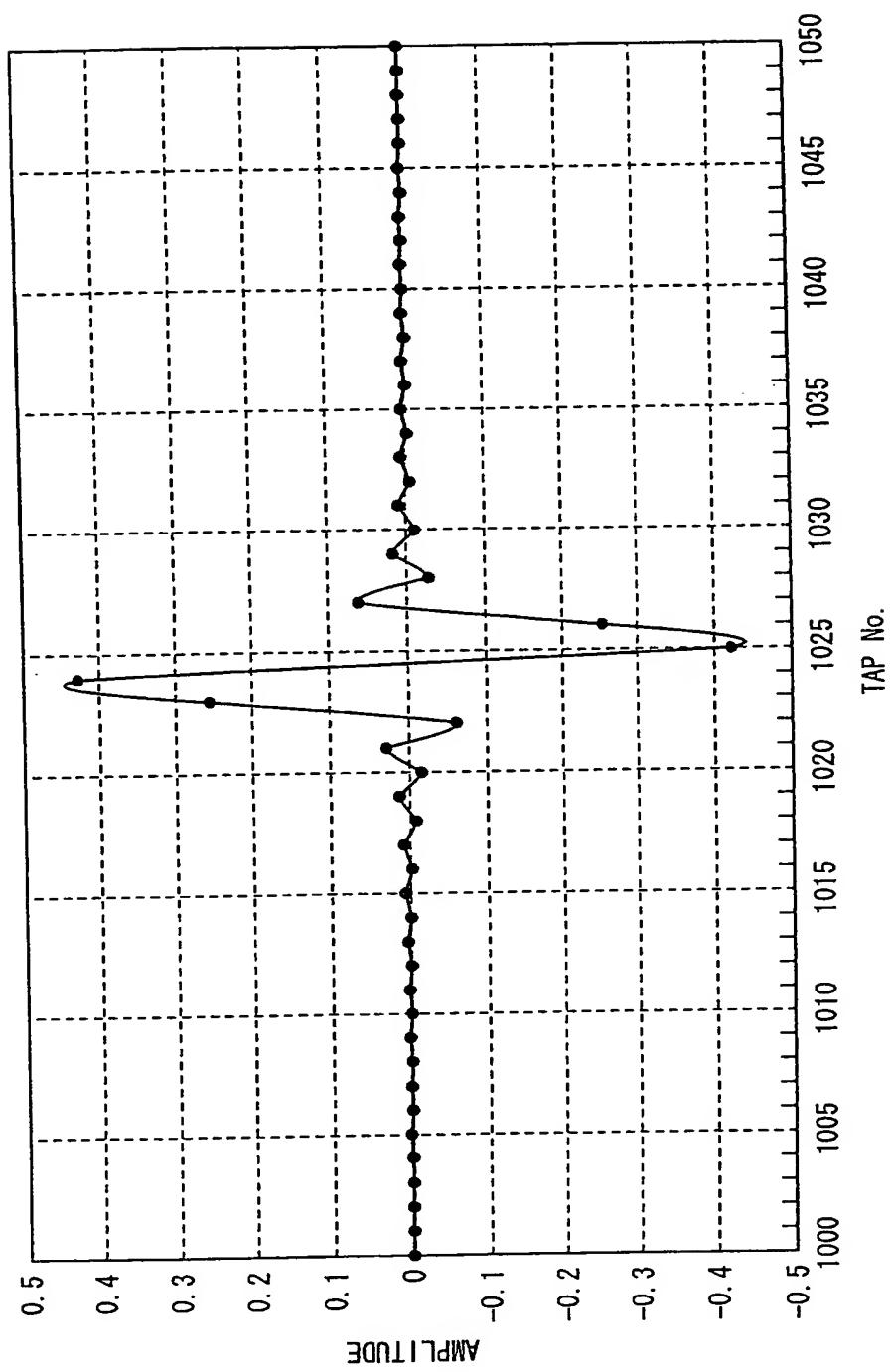
[FIG.15]



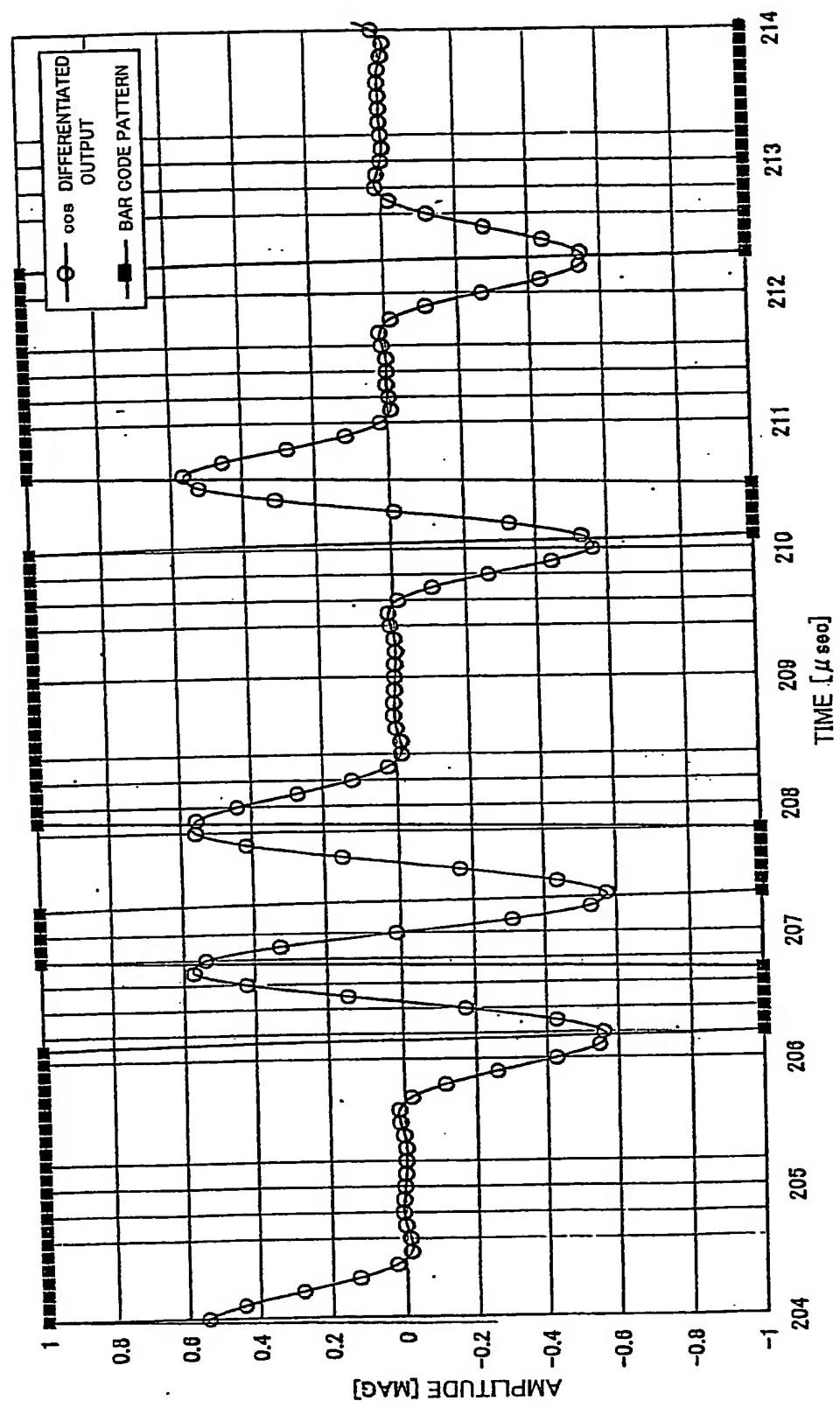
[FIG.16]



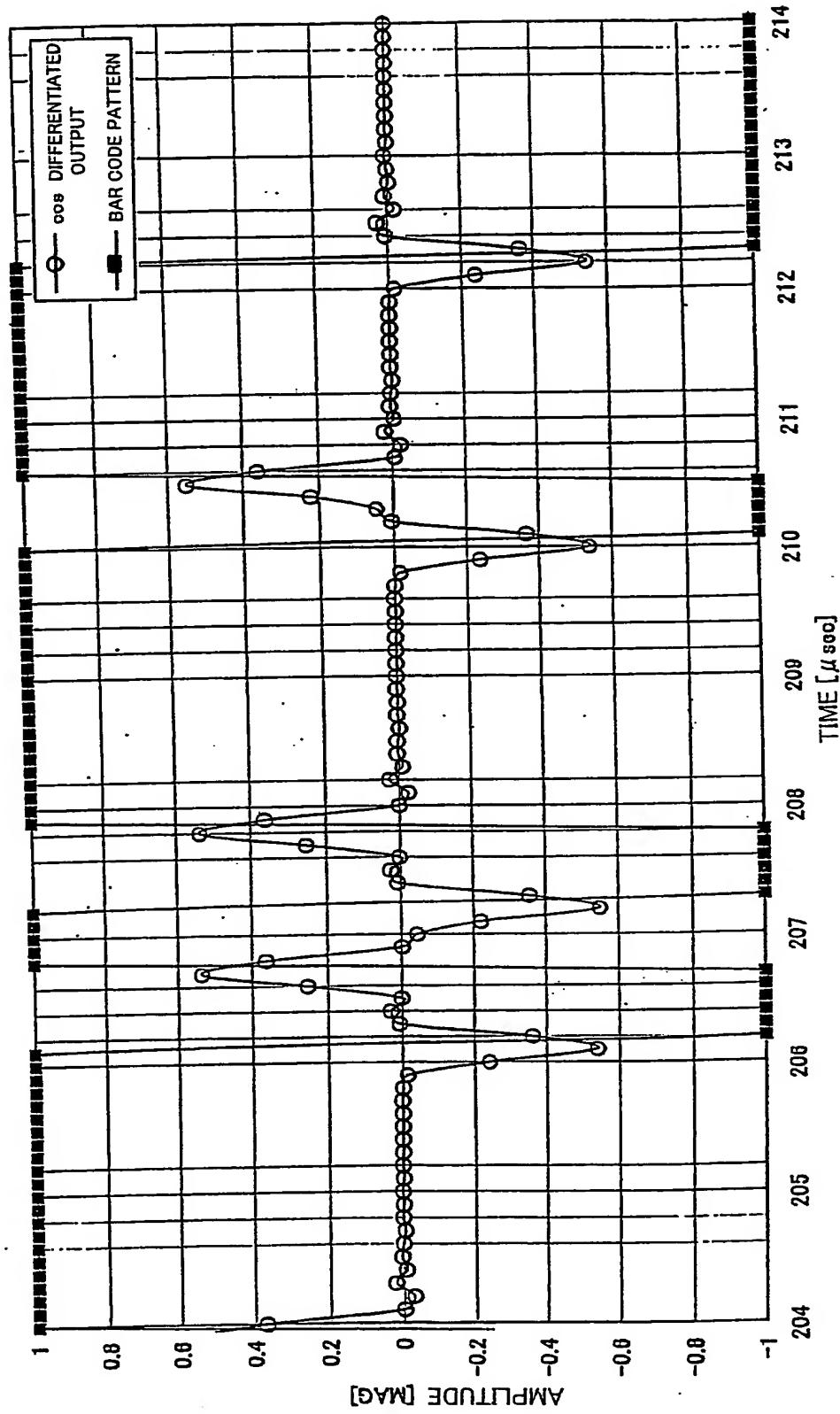
[FIG. 17]



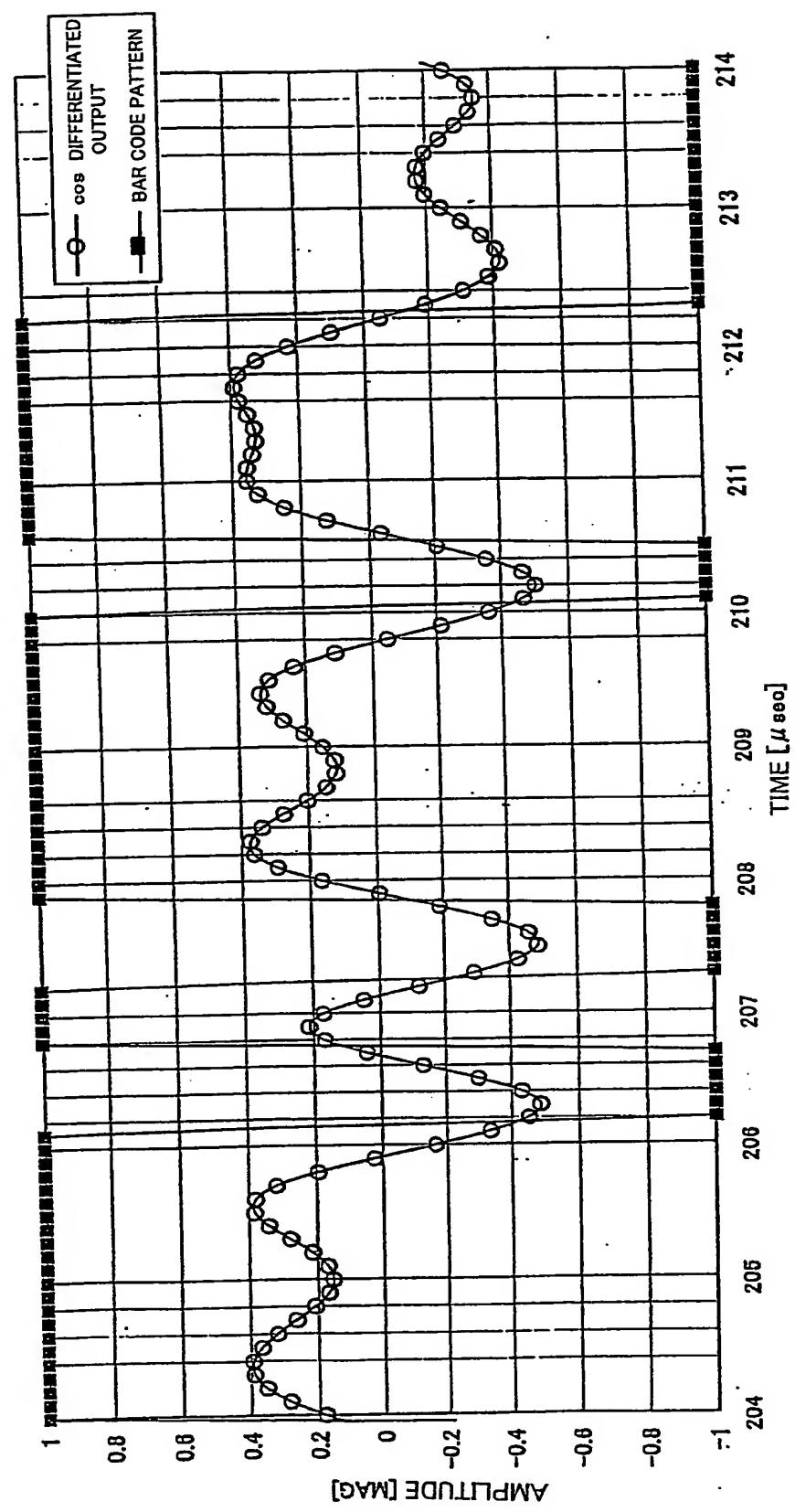
[FIG. 18]



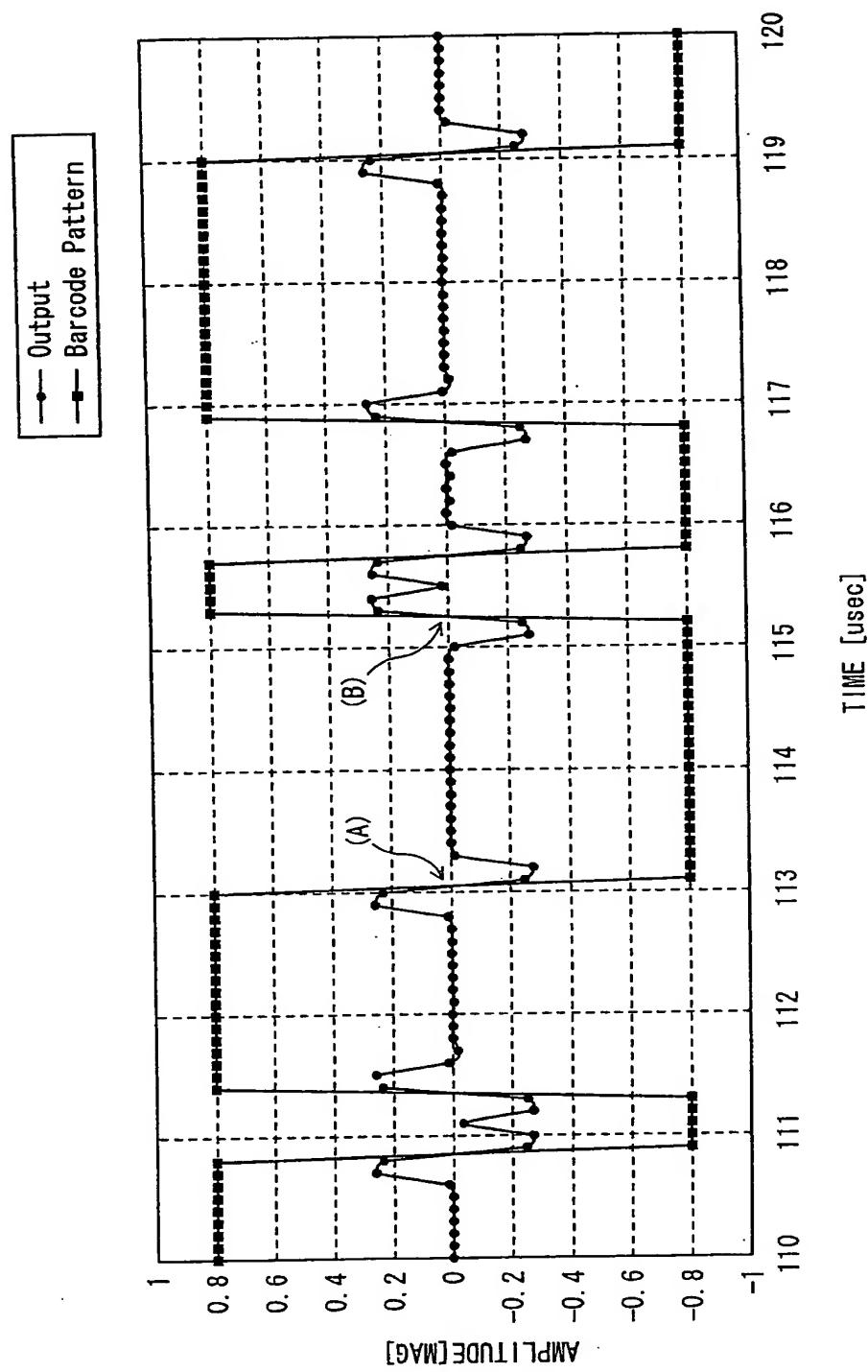
[FIG.19]



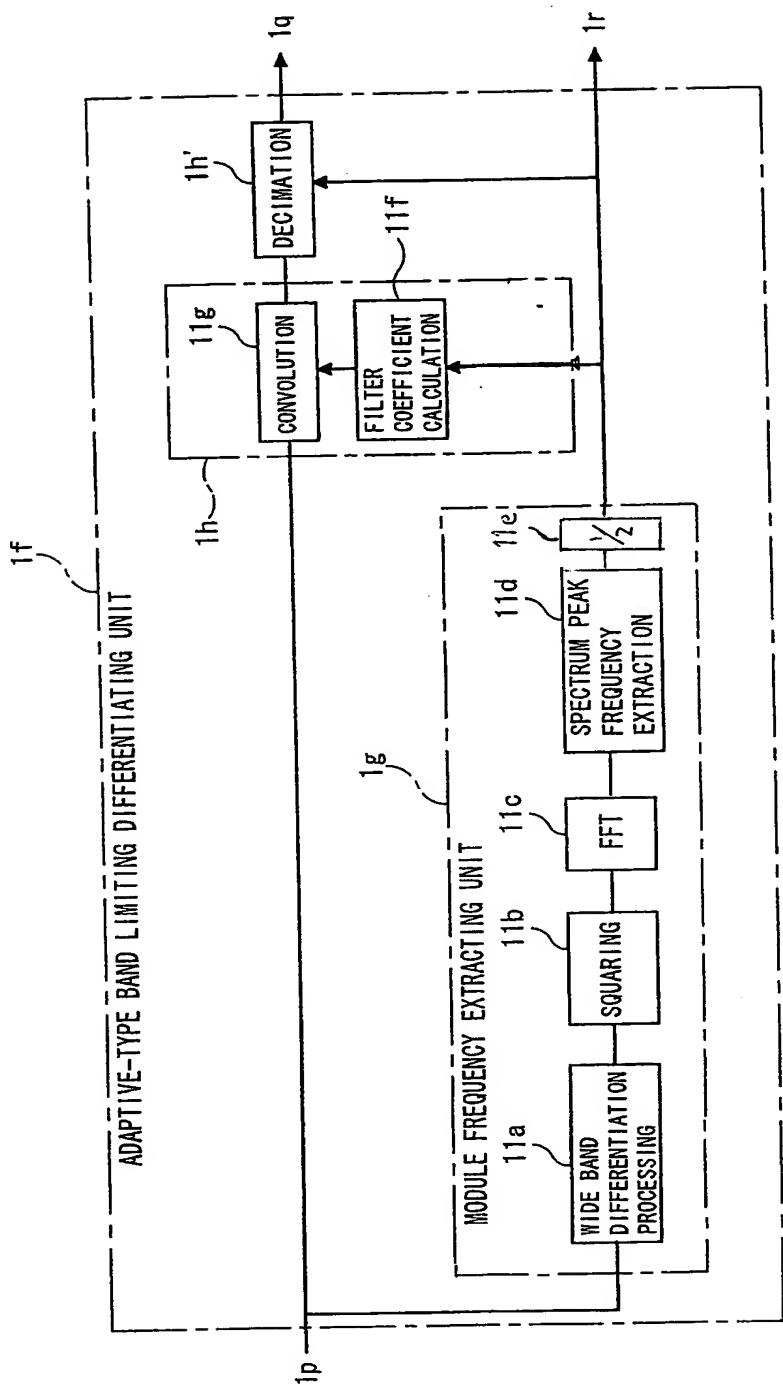
[FIG.20]



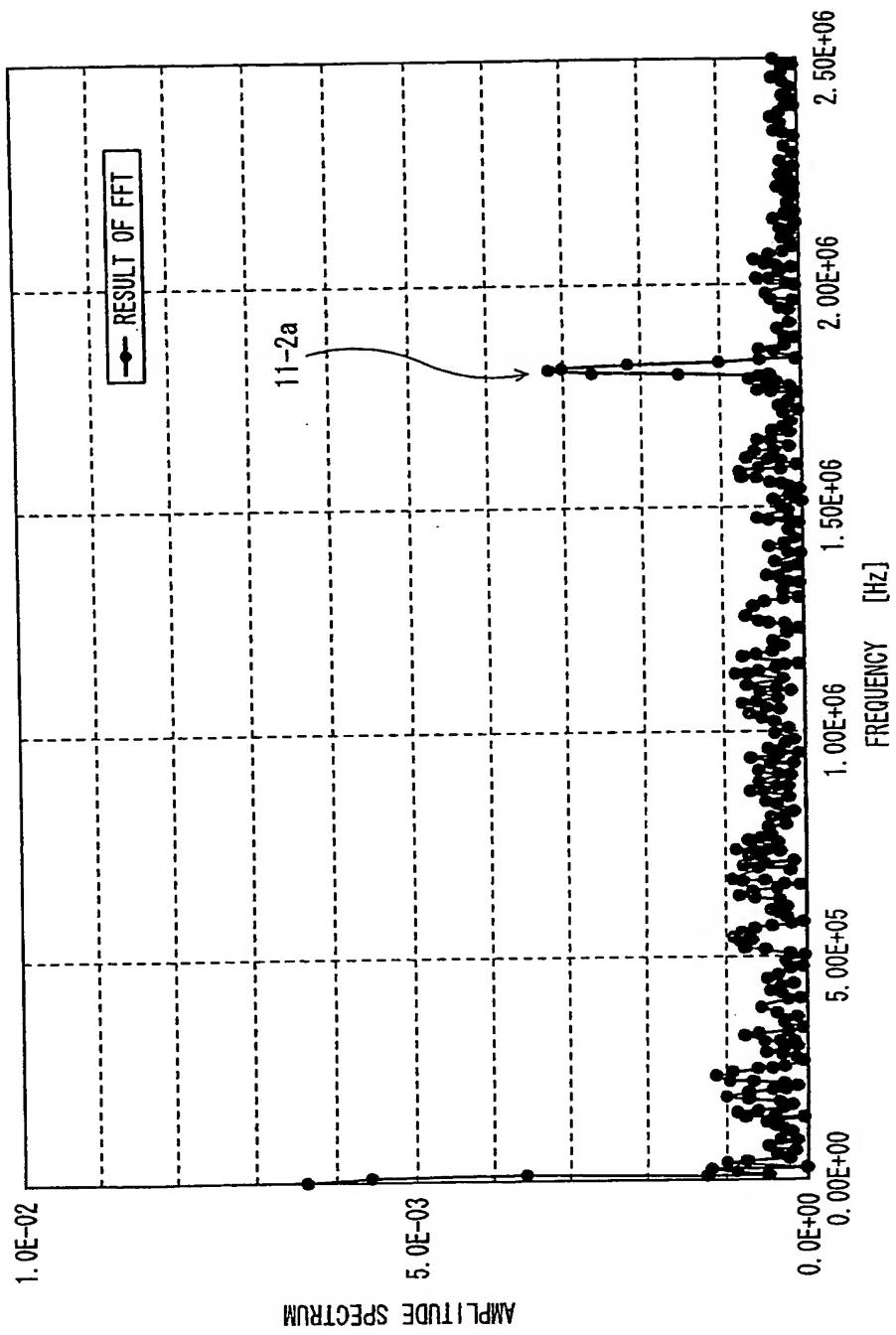
[FIG.21]



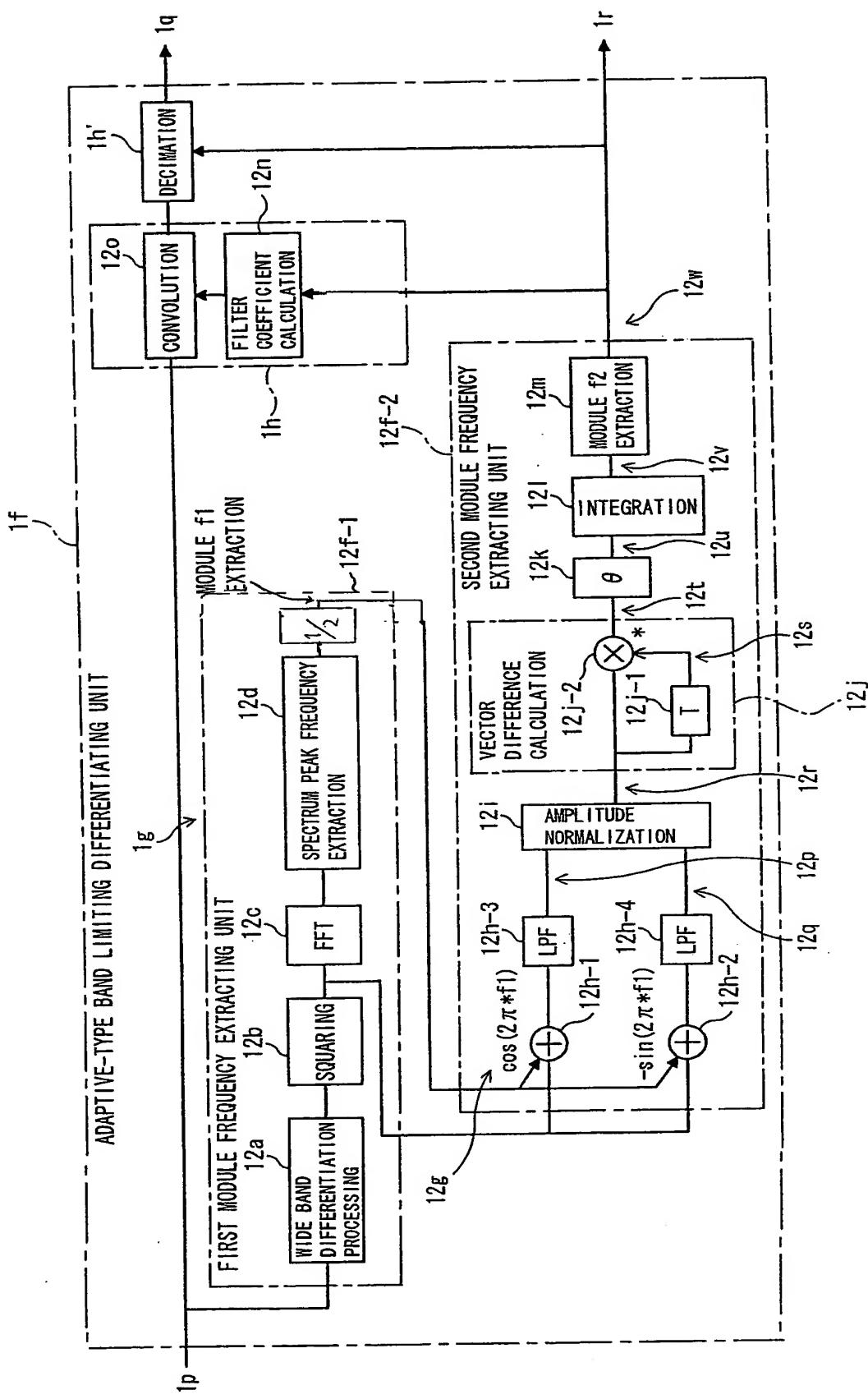
[FIG. 22]



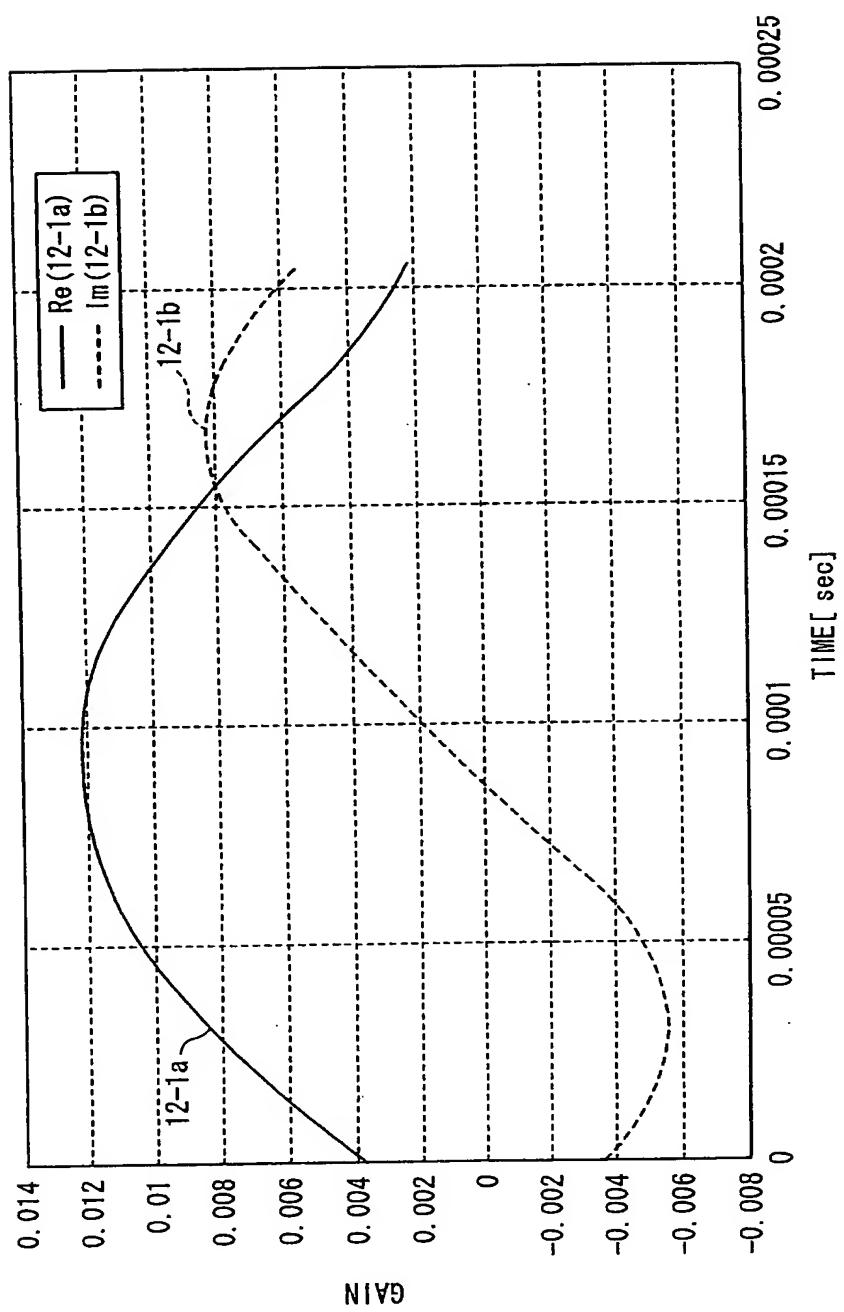
[FIG.23]



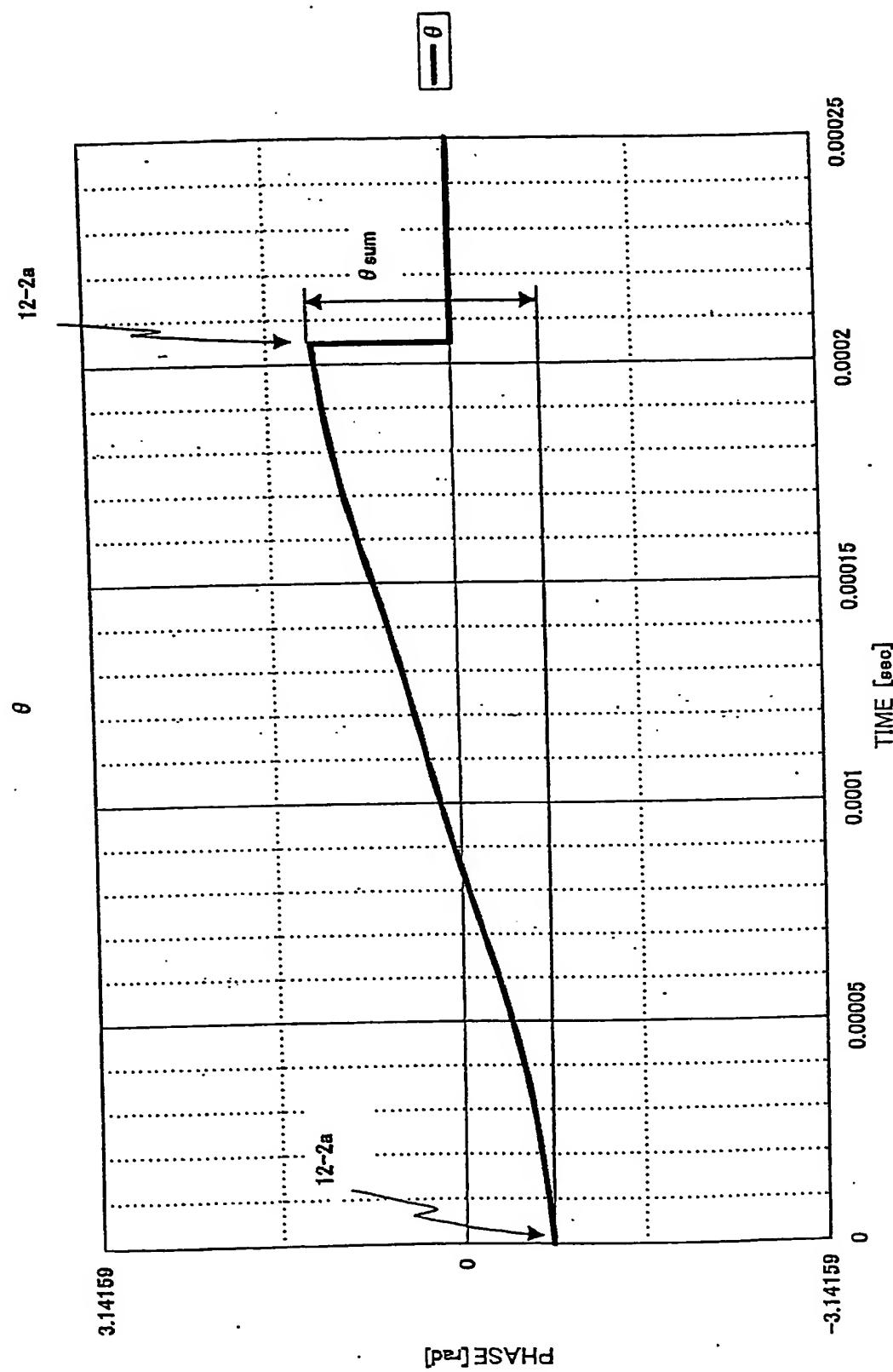
[FIG. 24]



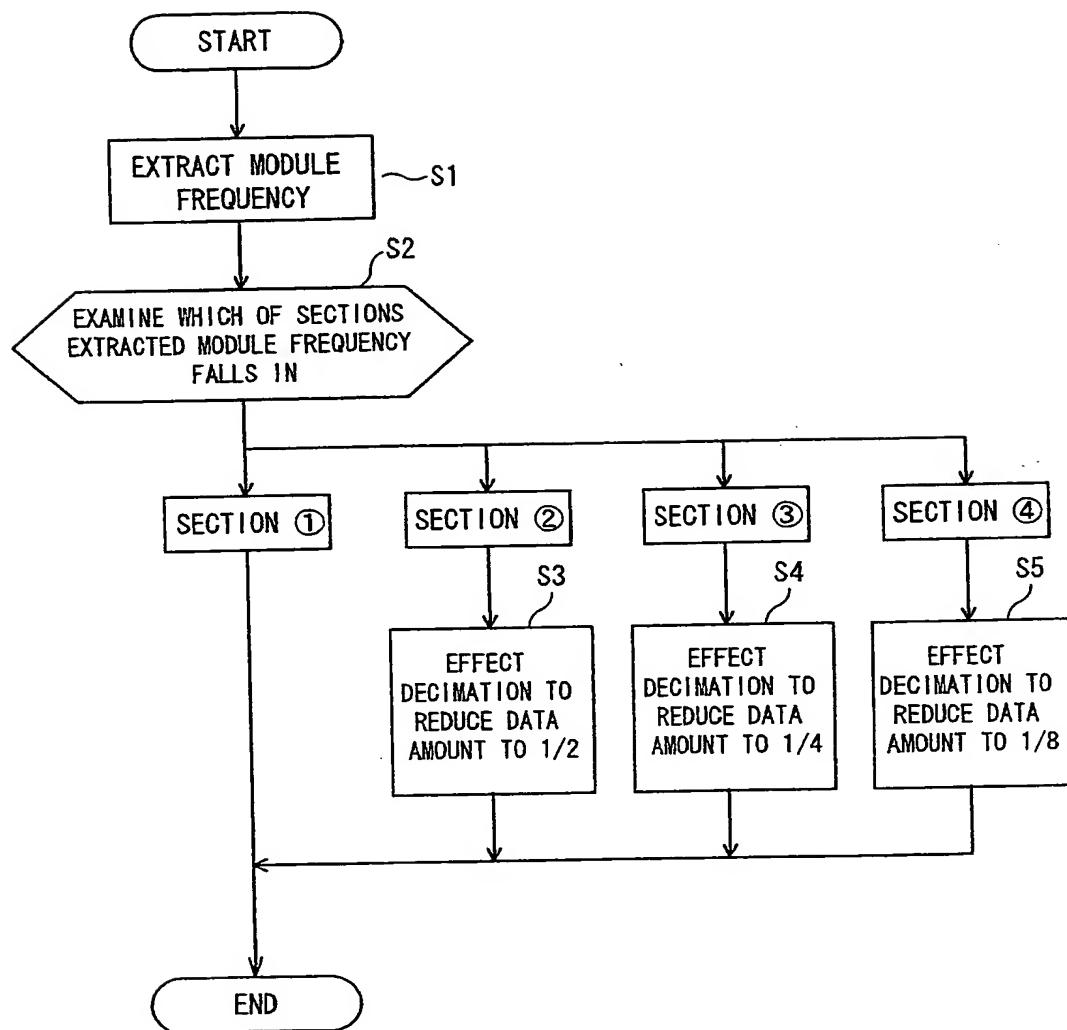
[FIG. 25]



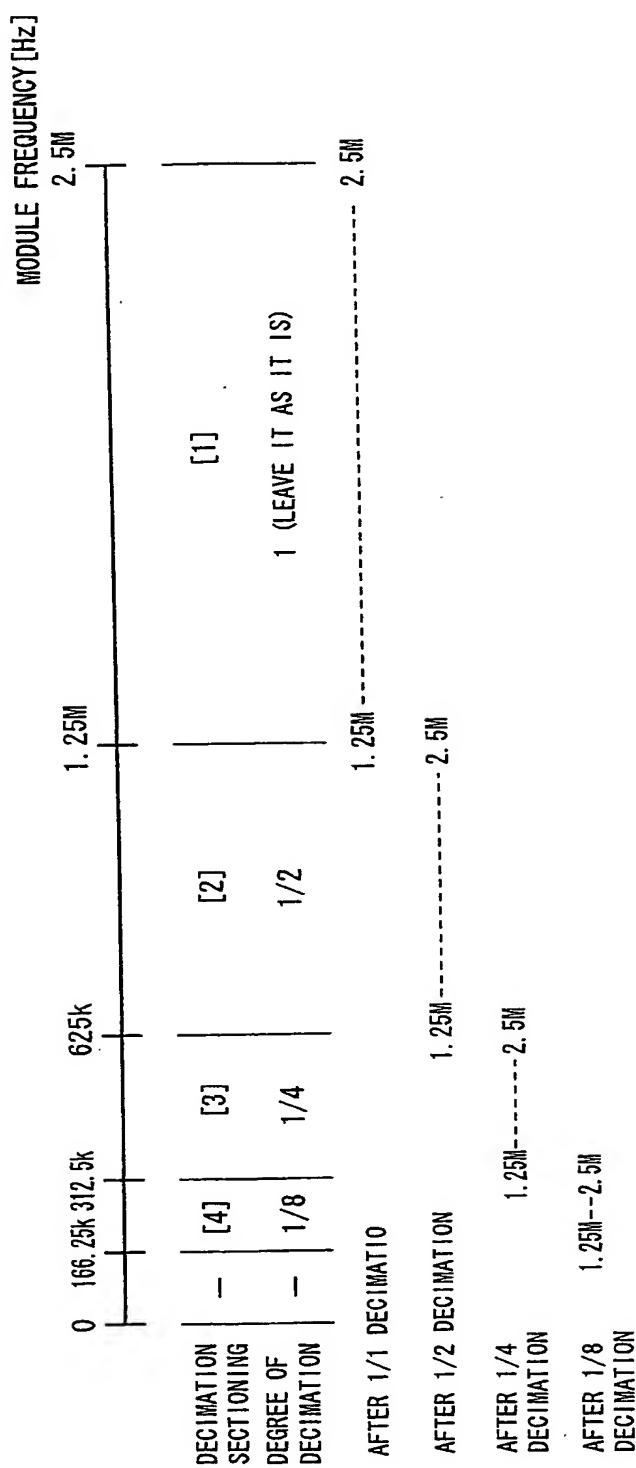
[FIG.26]



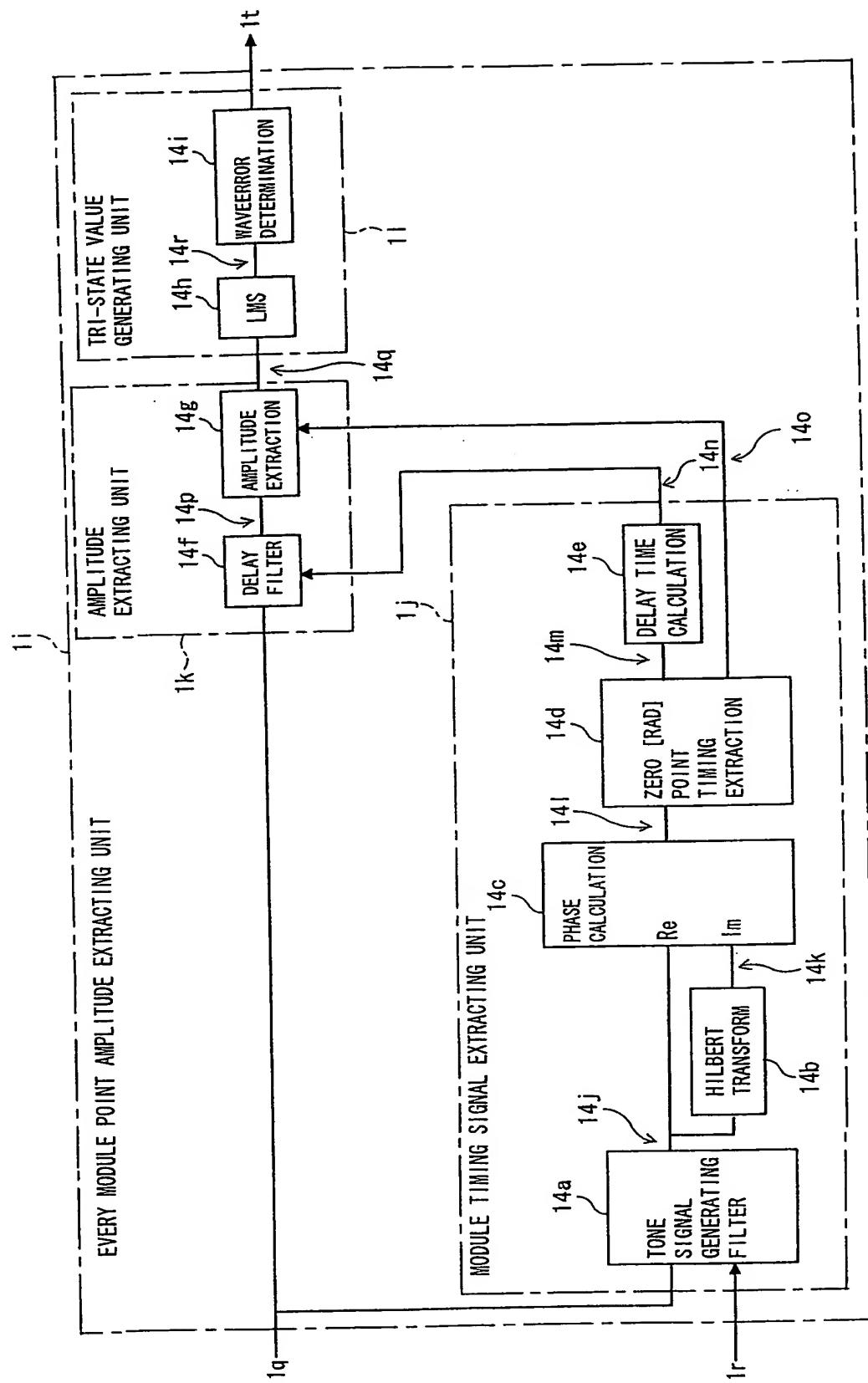
[FIG.27]



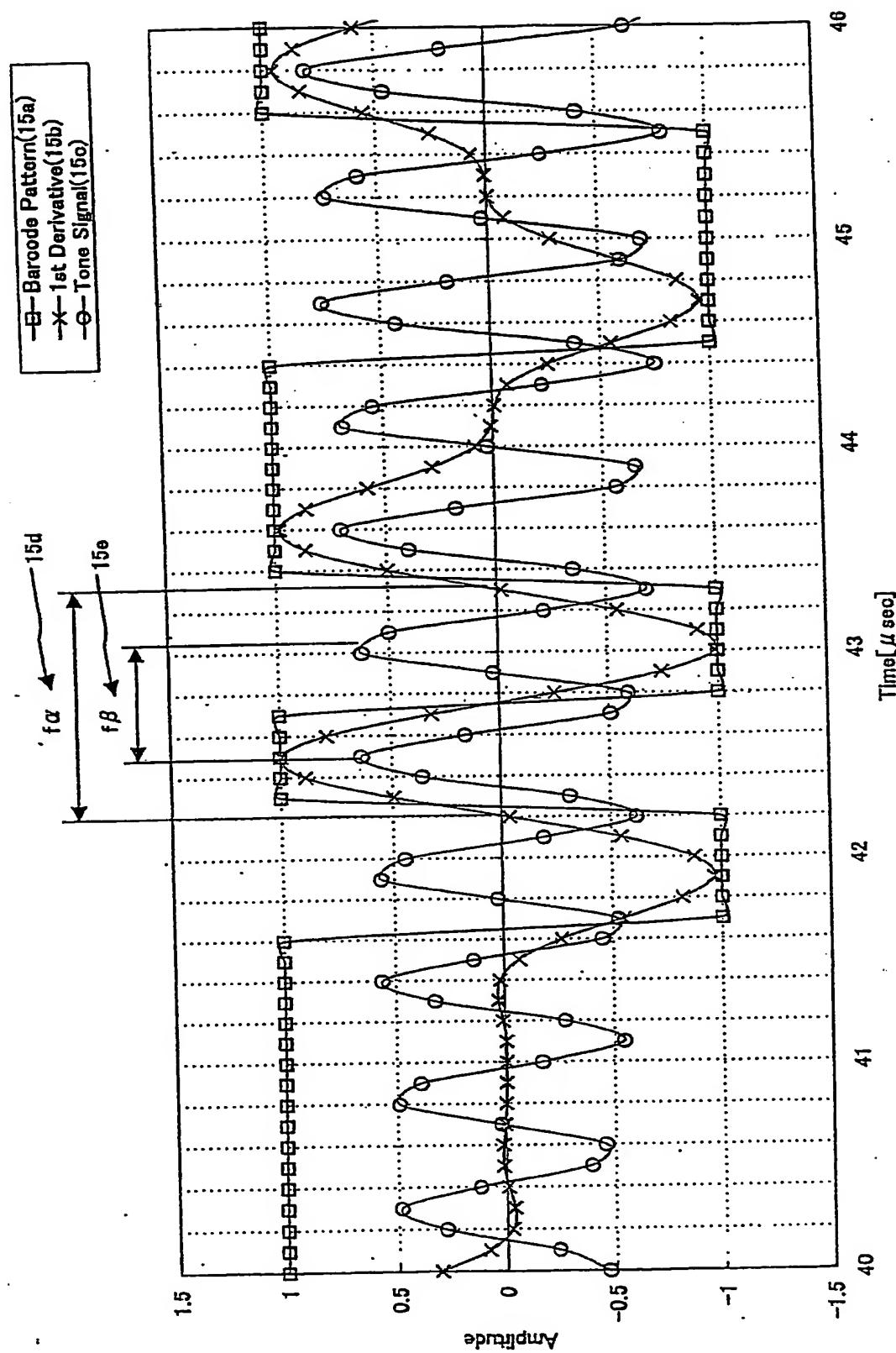
[FIG.28]



[FIG.29]

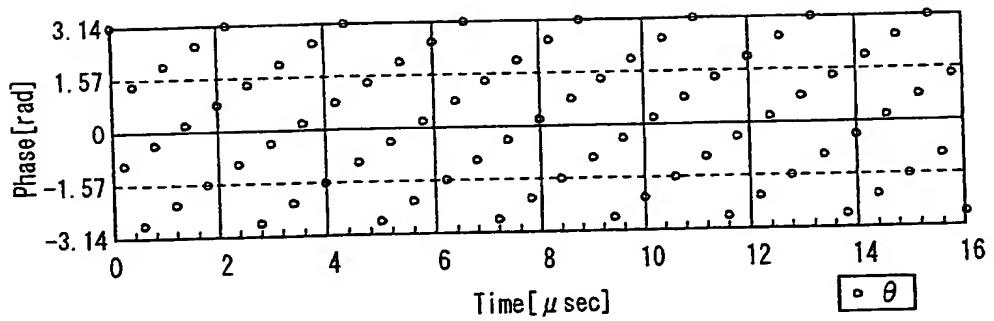


[FIG.30]

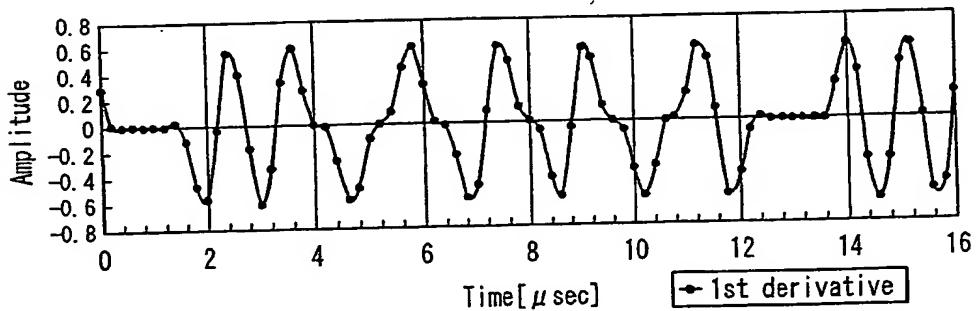


[FIG.31]

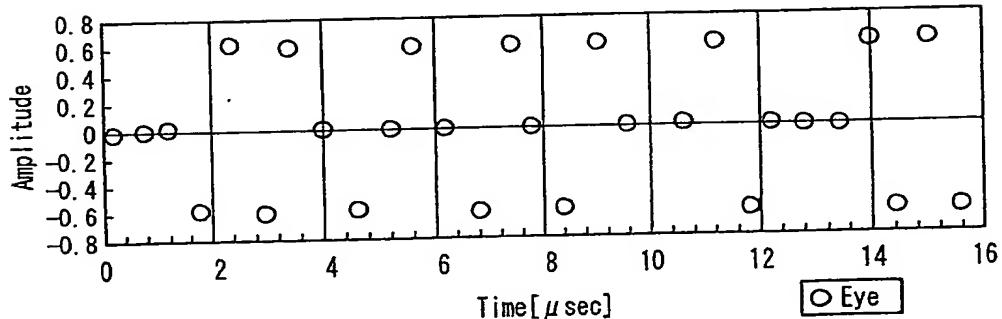
(a)



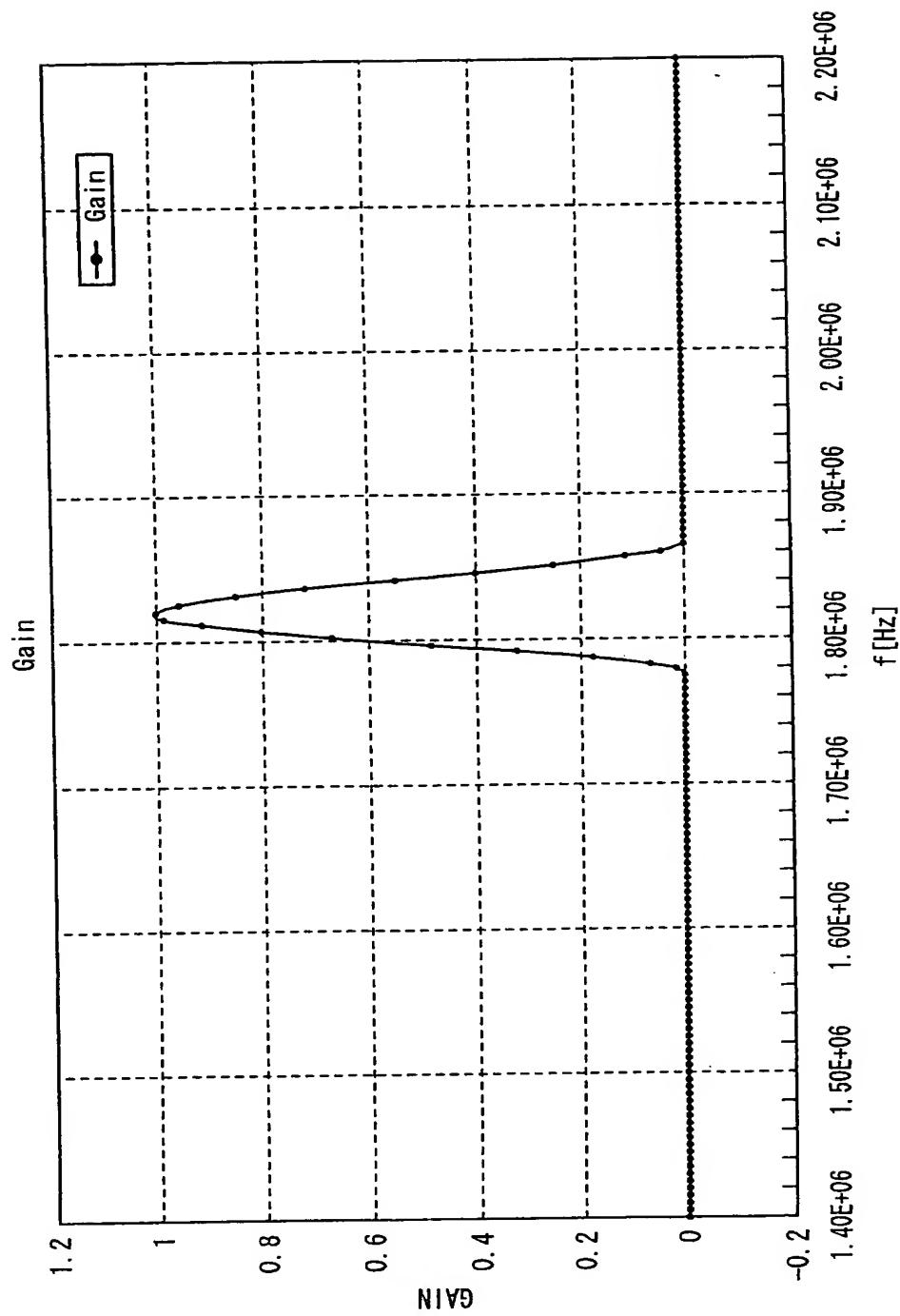
(b)



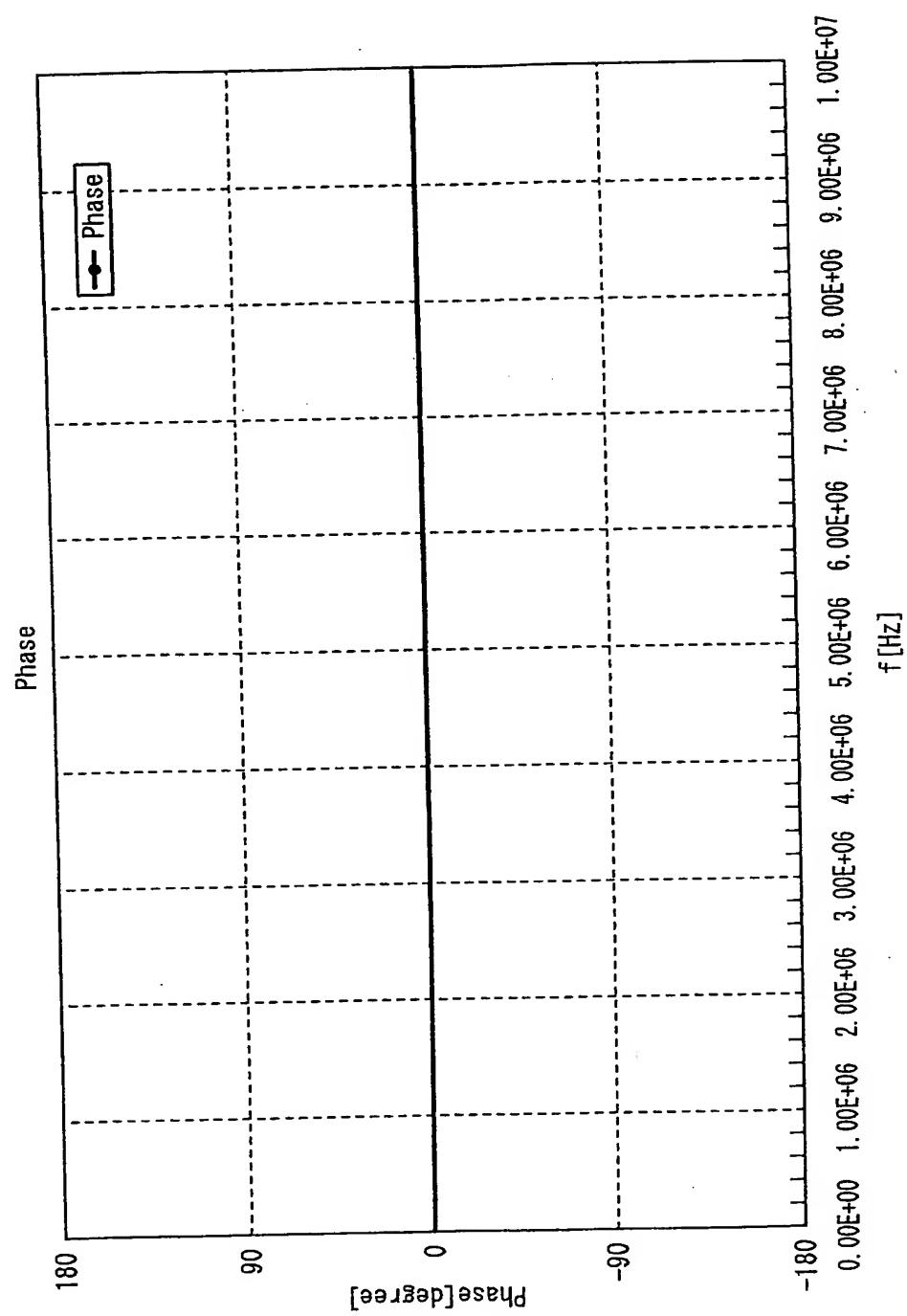
(c)



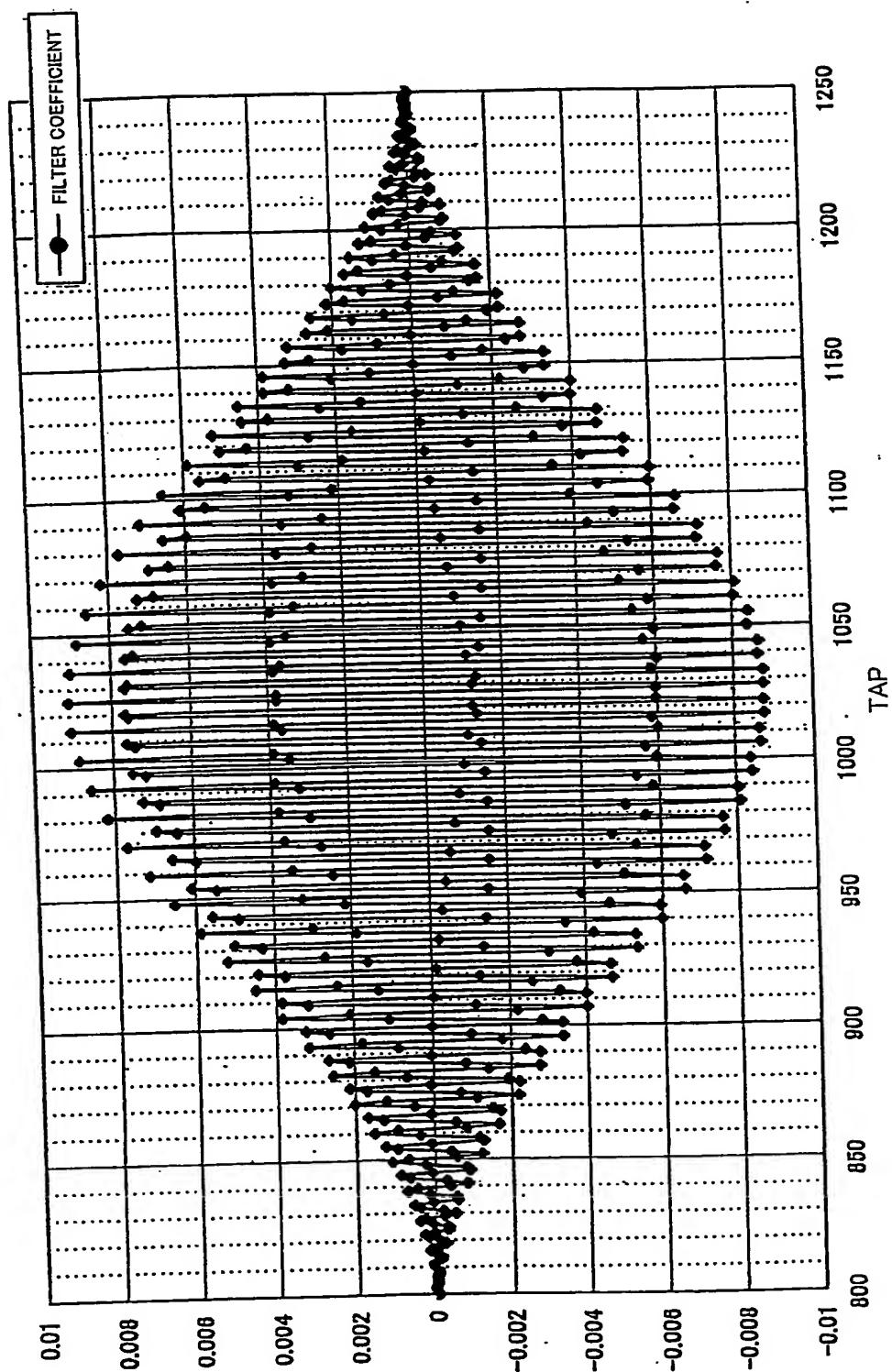
[FIG.32]



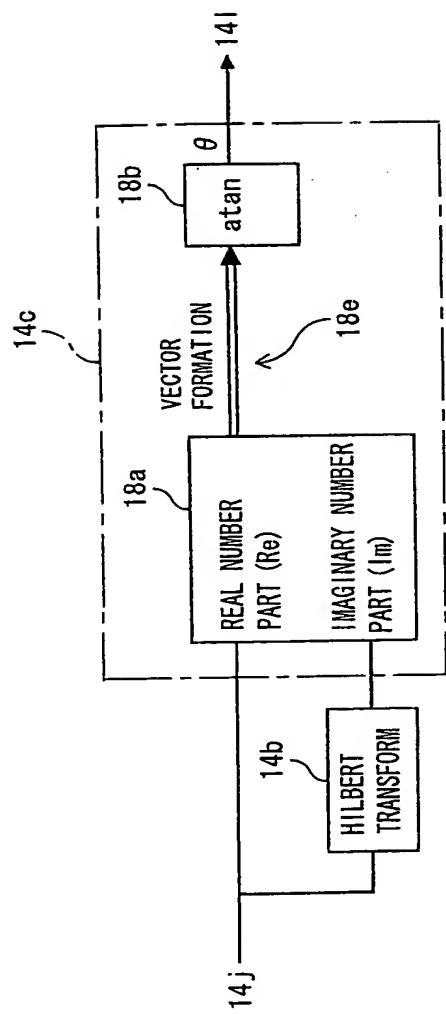
[FIG.33]



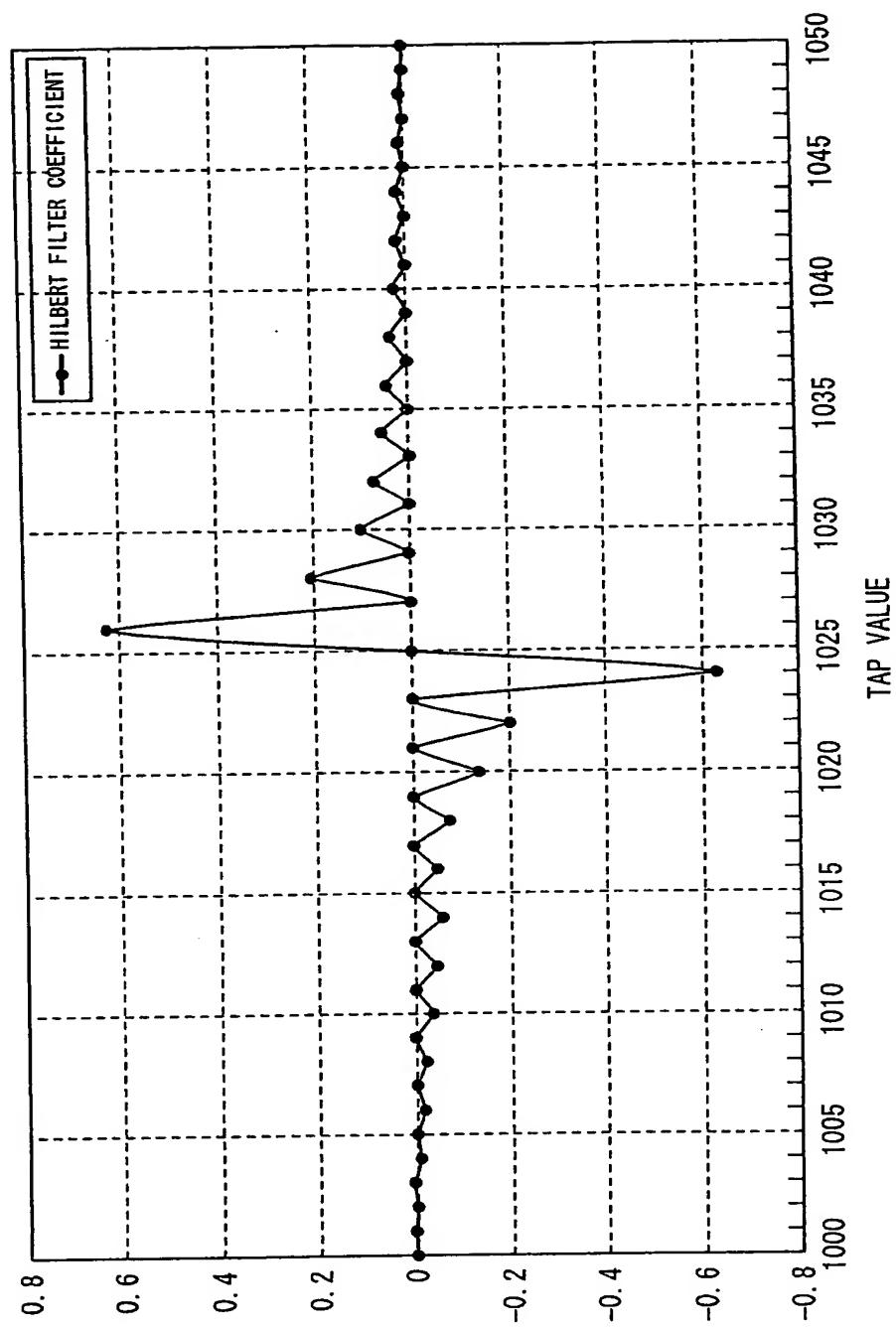
[FIG.34]



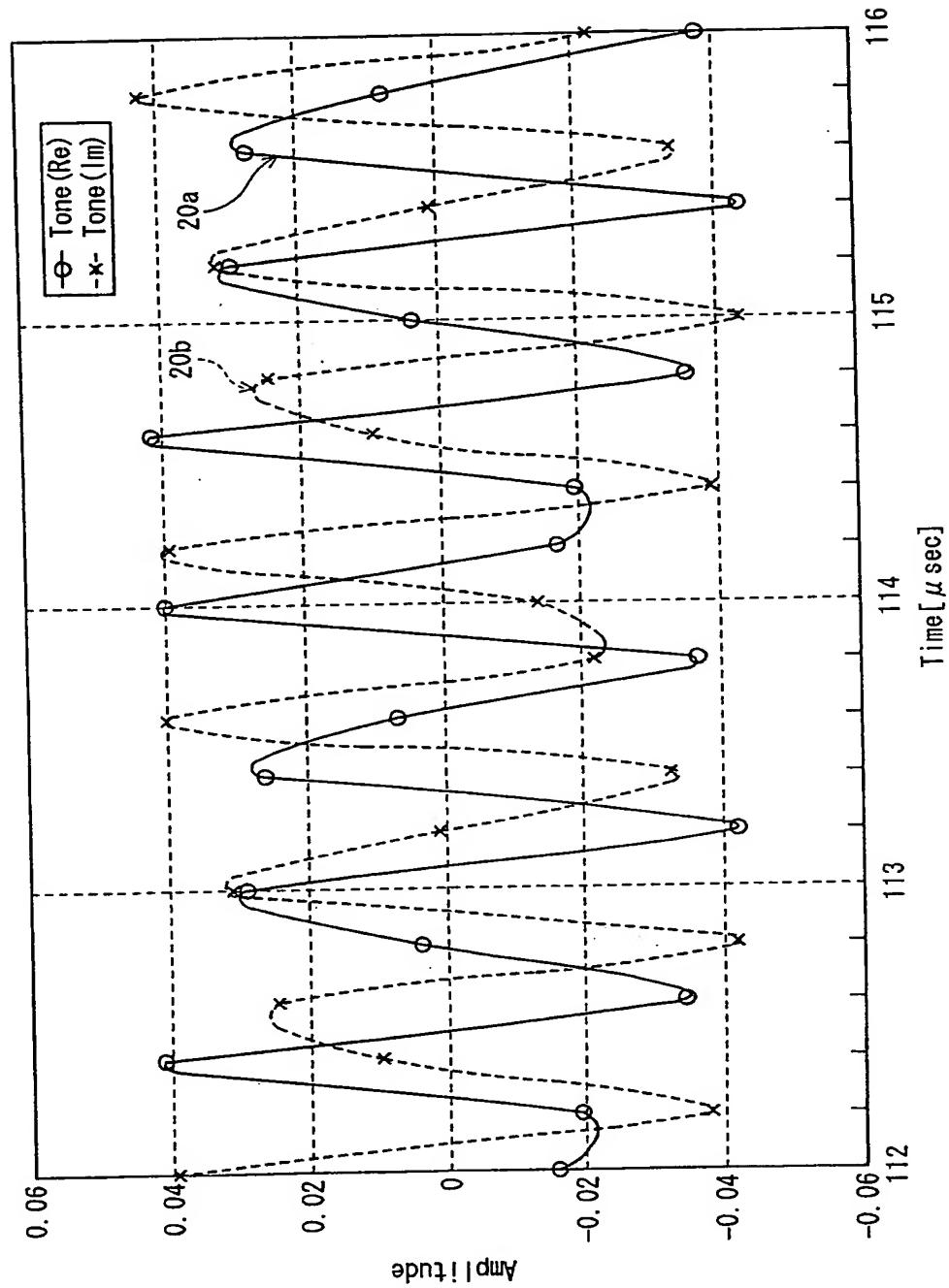
[FIG.35]



[FIG. 36]

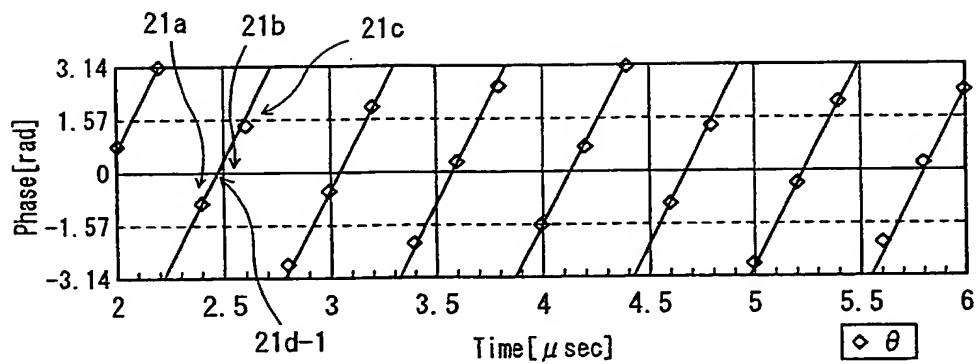


[FIG.37]

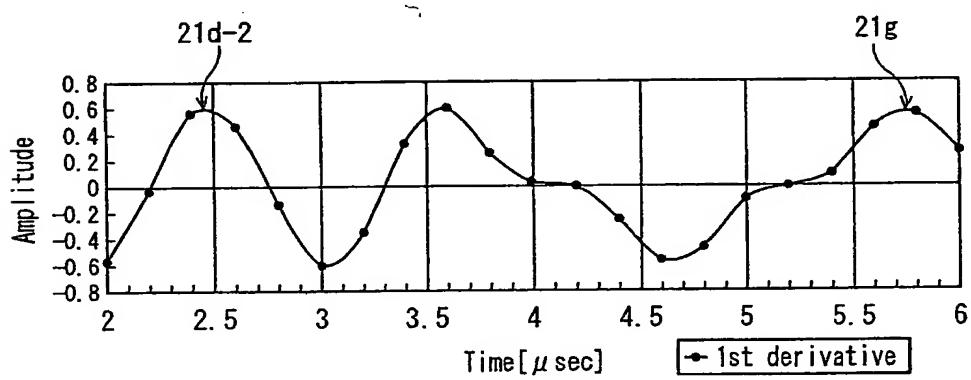


[FIG.38]

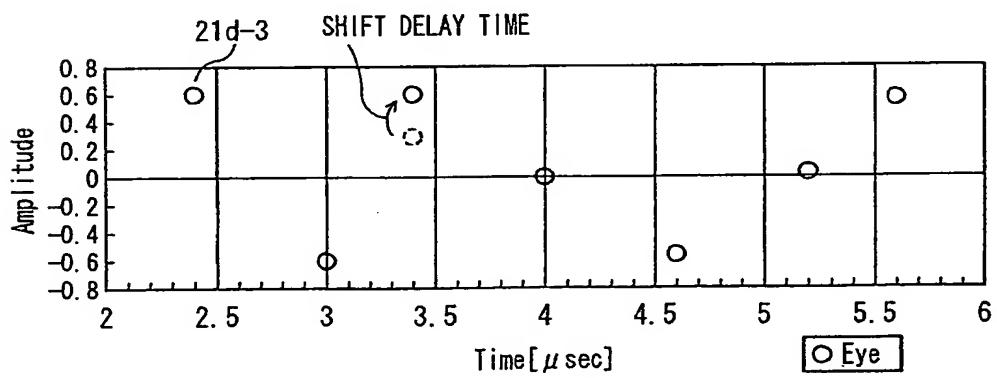
(a)



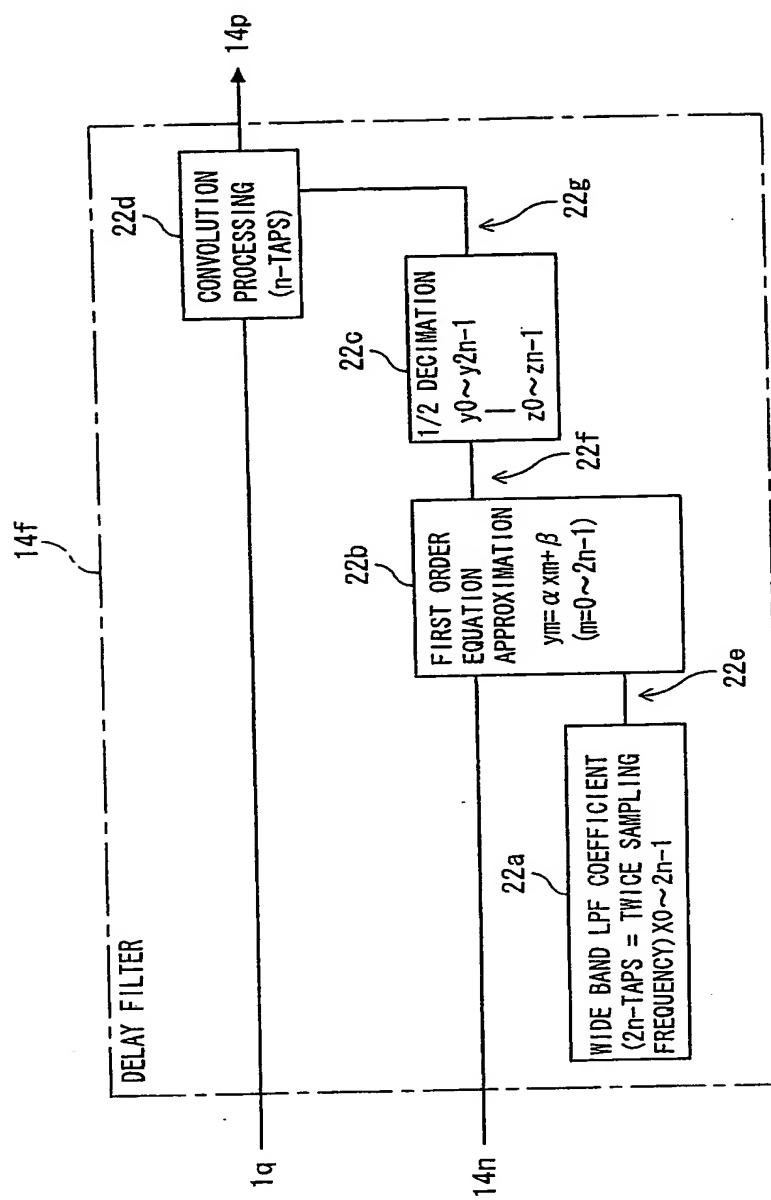
(b)



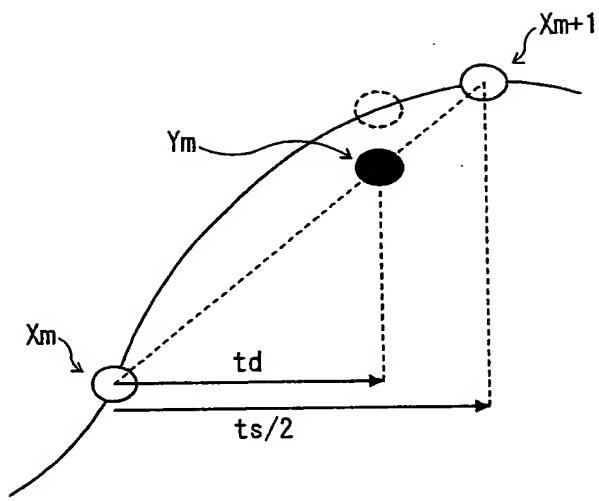
(c)



[FIG.39]

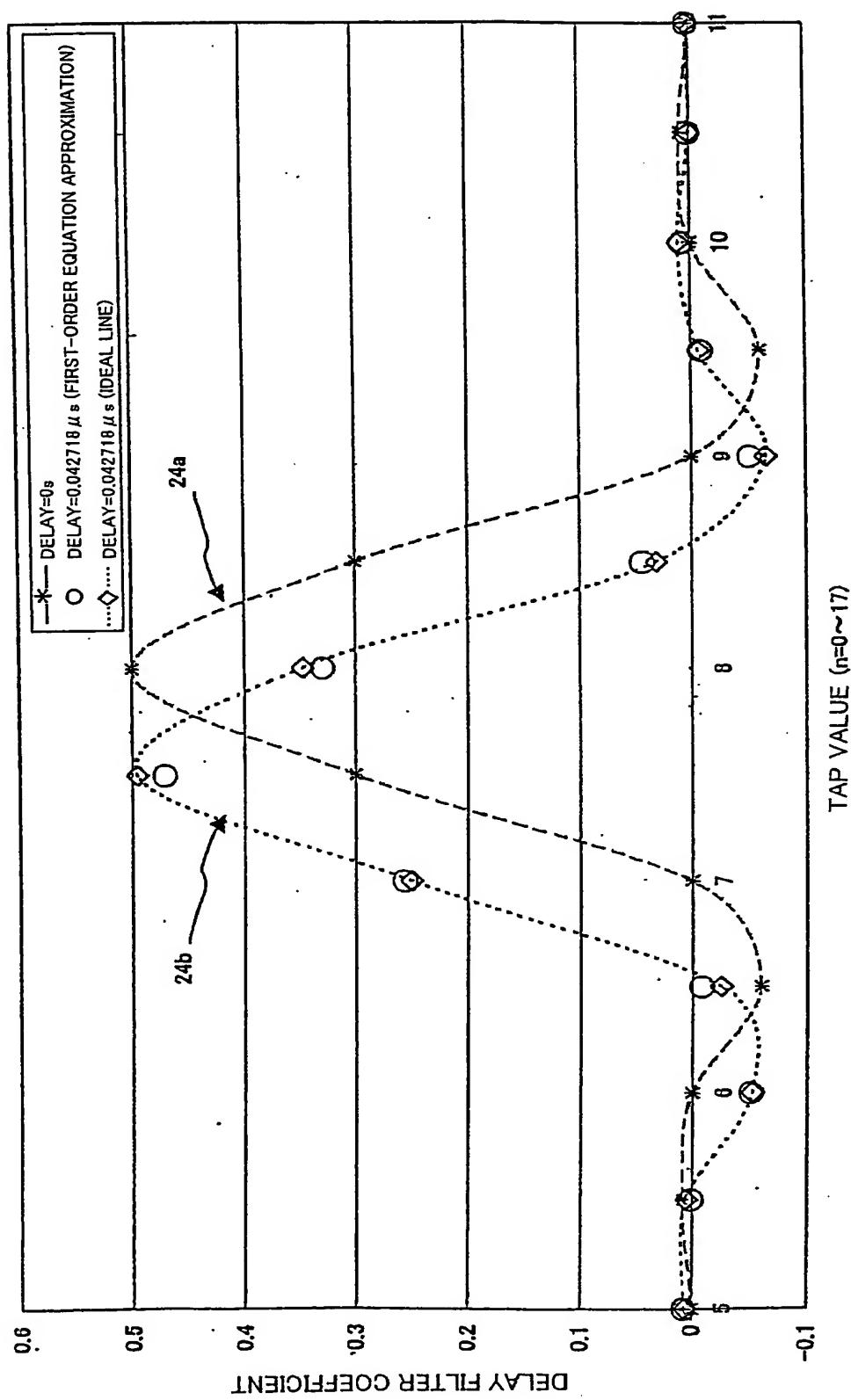


[FIG.40]

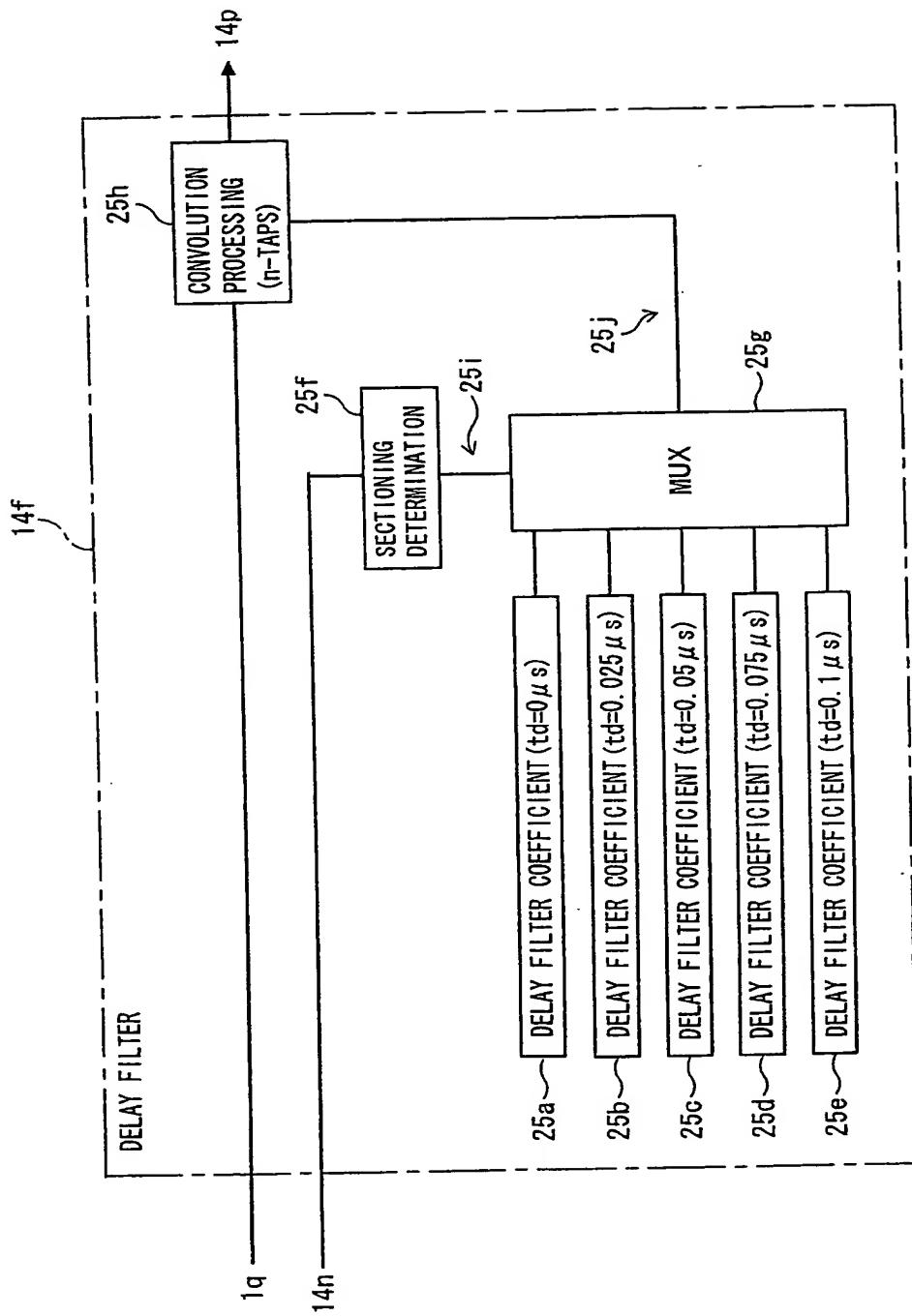


$$y_m = \frac{x_{m+1} - x_m}{ts/2} t_d + x_m$$

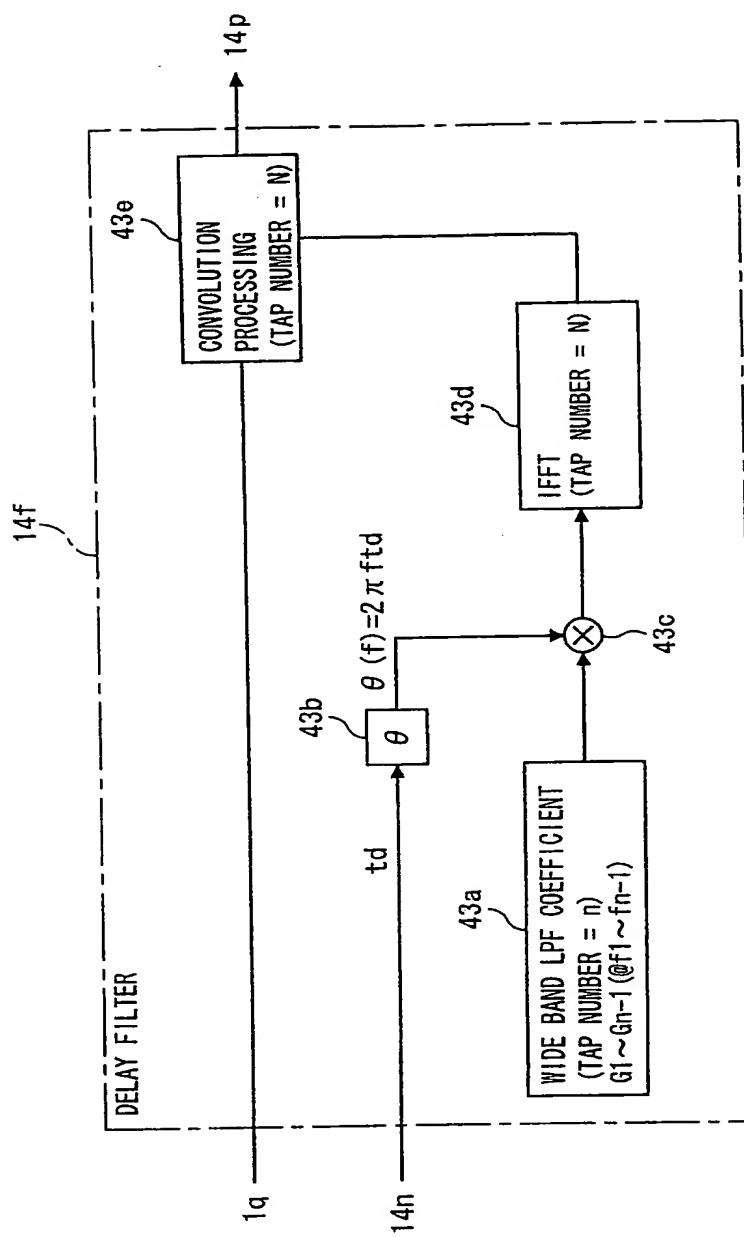
[FIG.41]



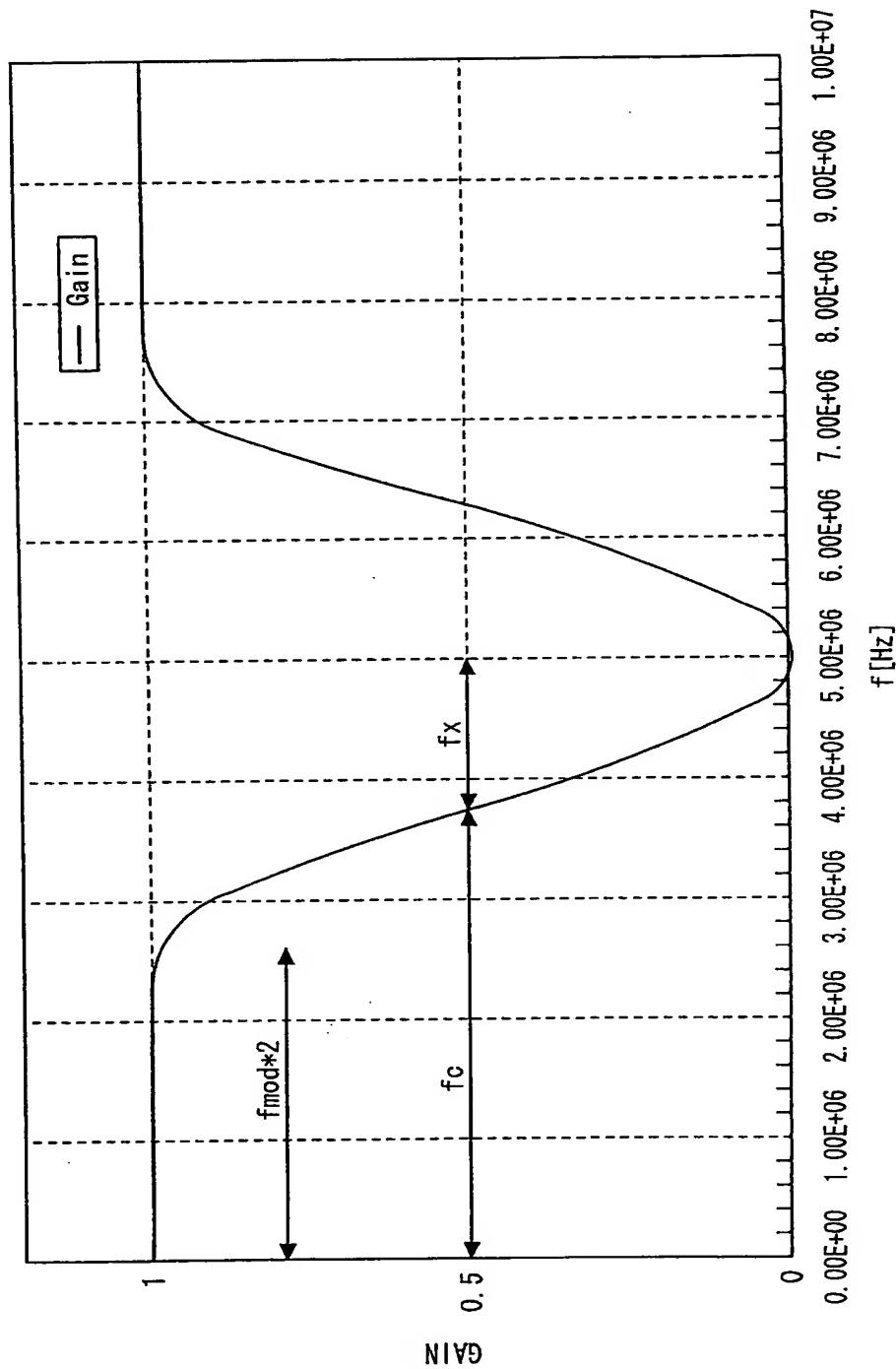
[FIG.42]



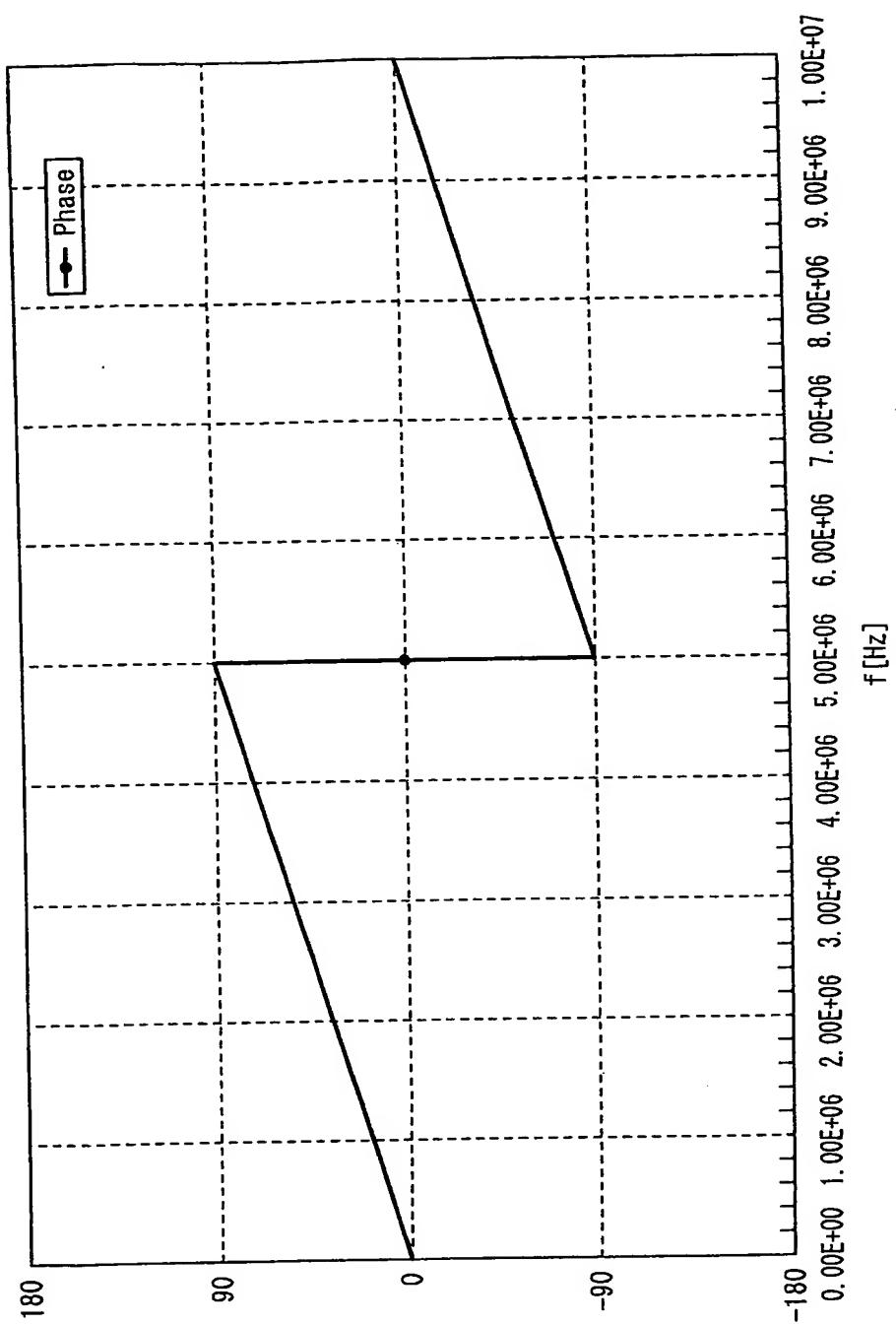
[FIG.43]



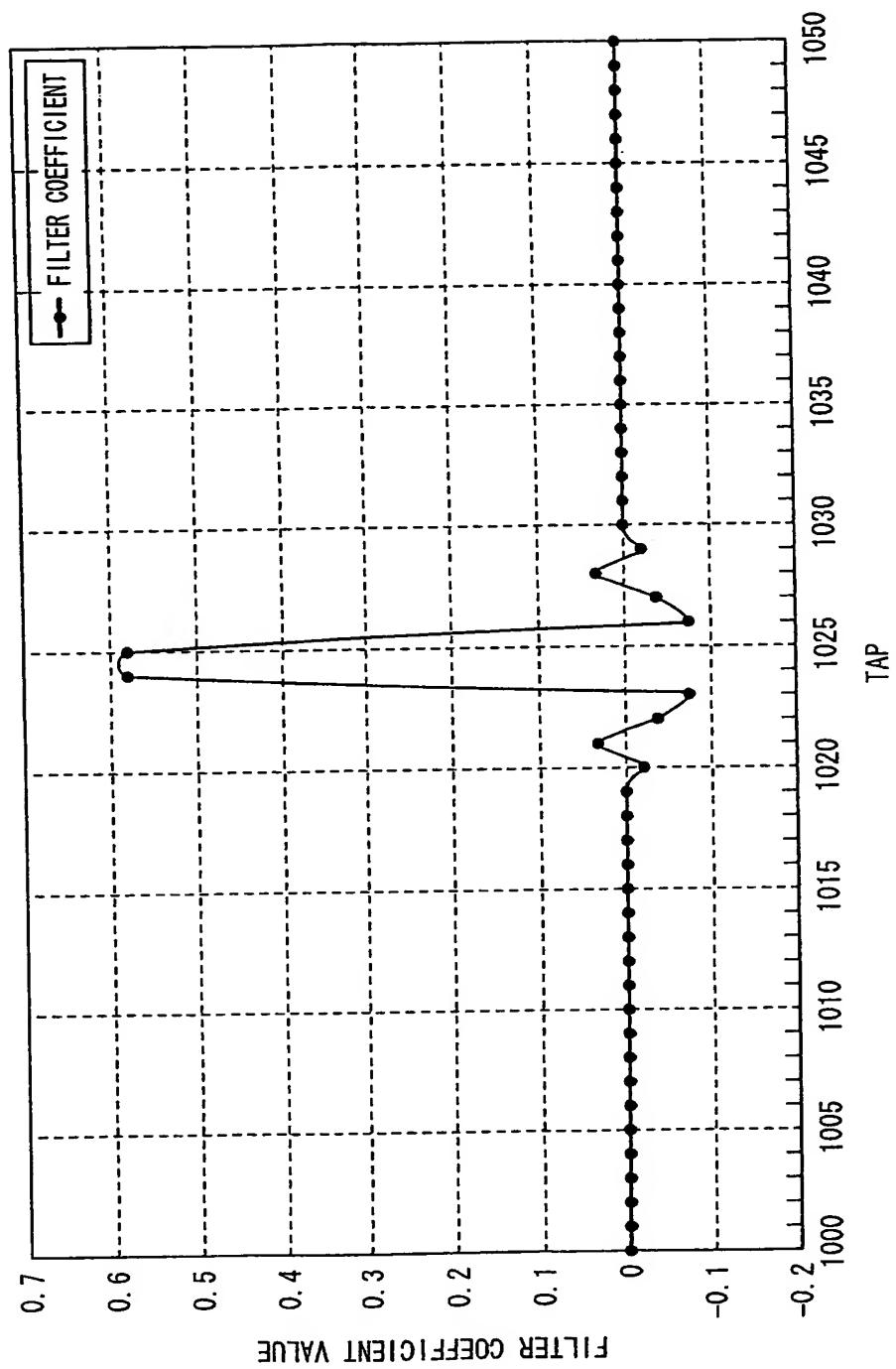
[FIG.44]



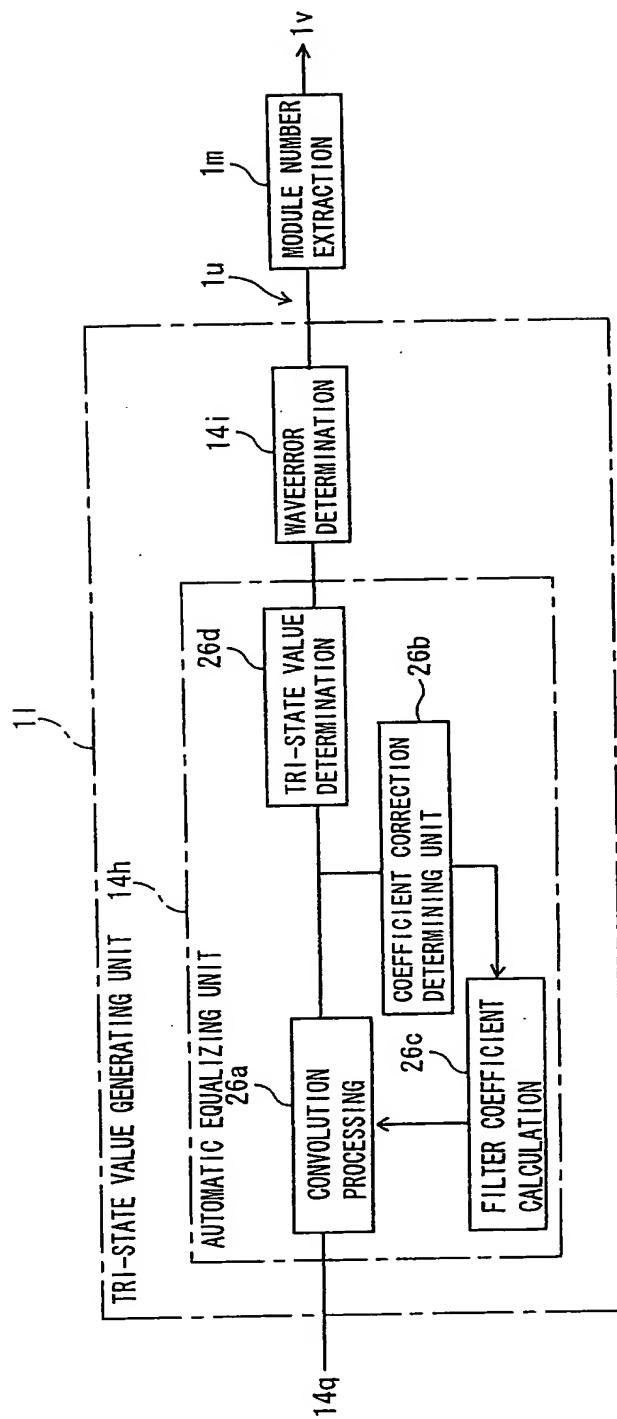
[FIG.45]



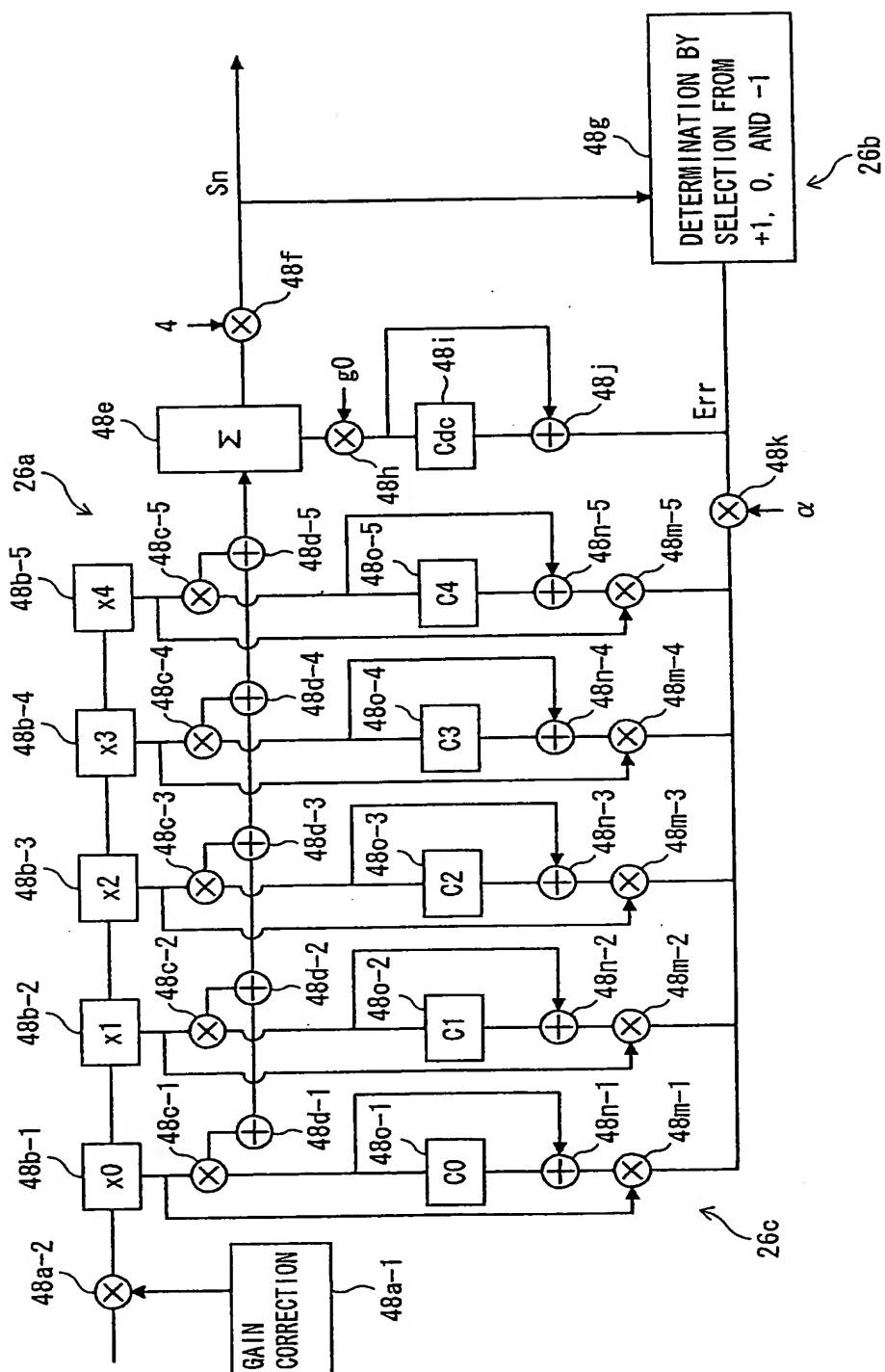
[FIG.46]



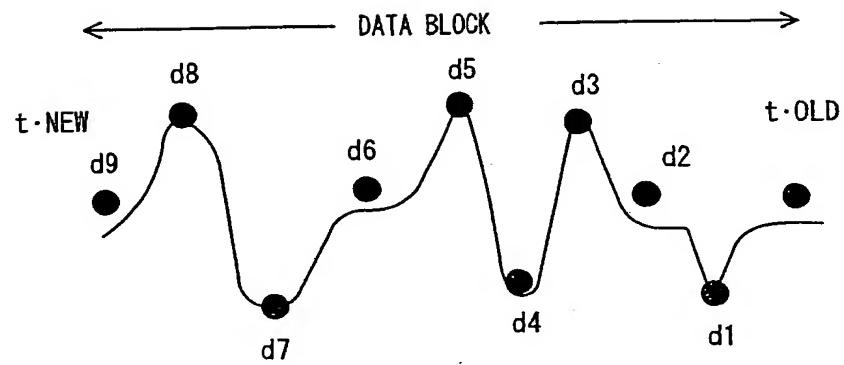
[FIG.47]



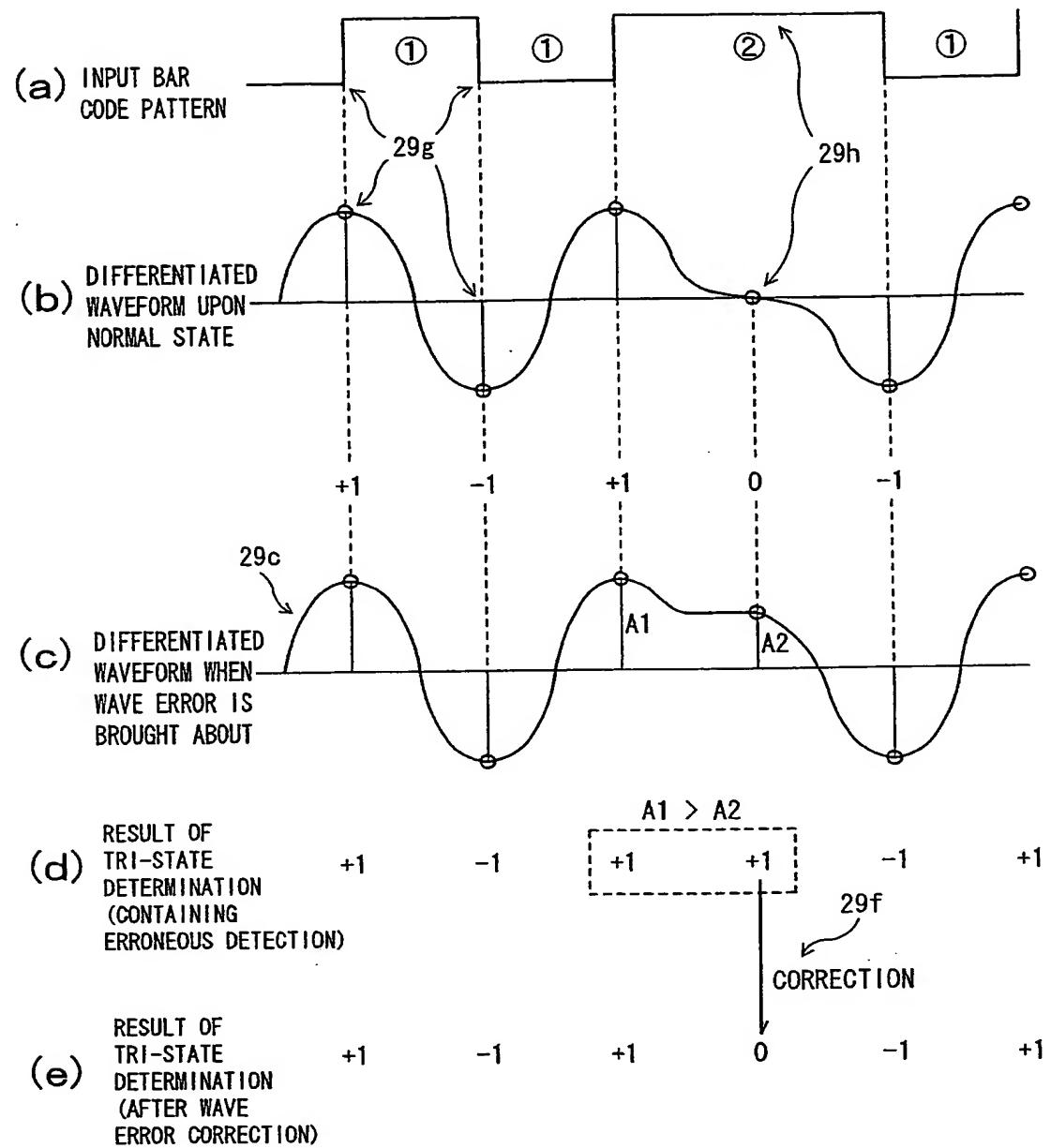
[FIG.48]



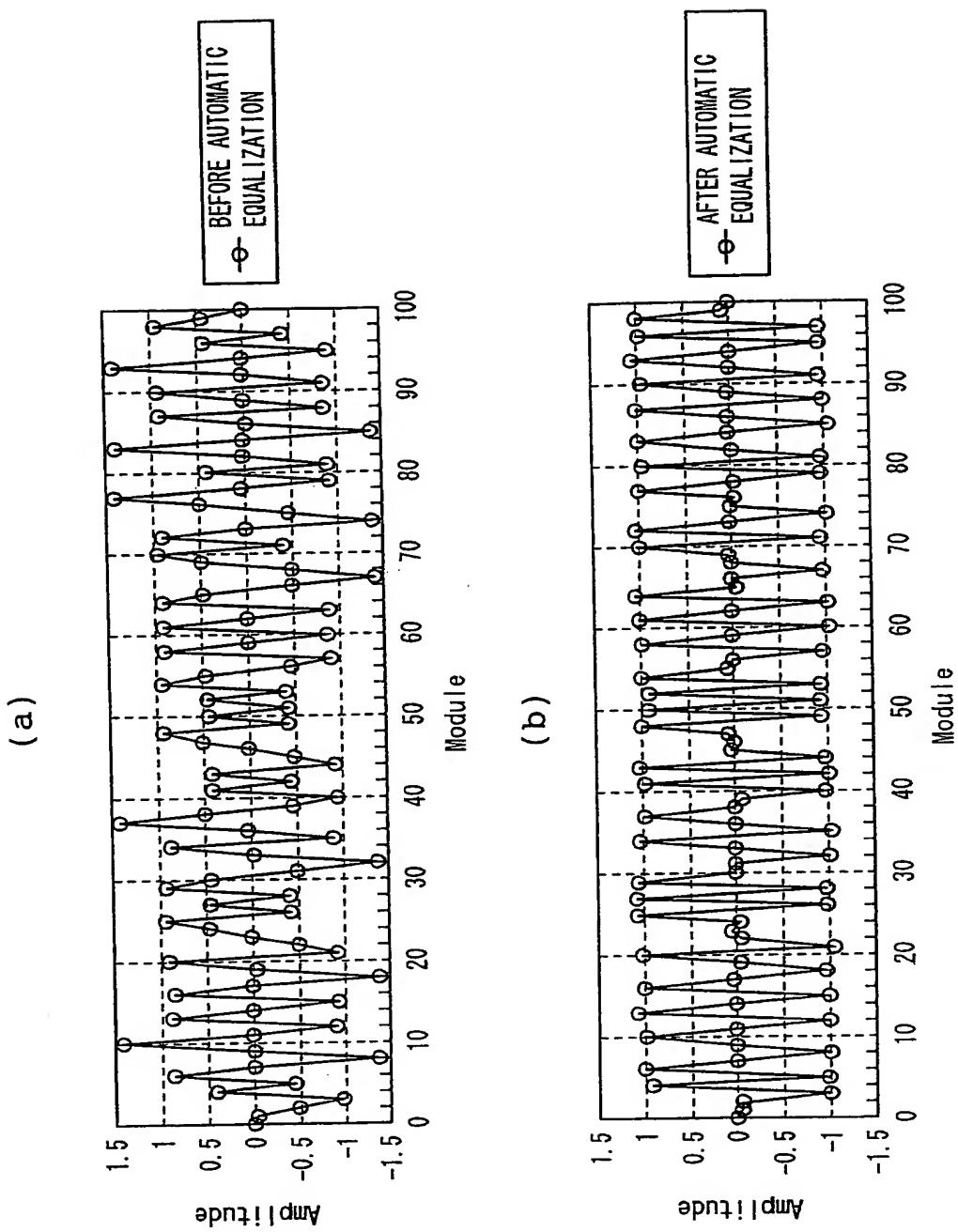
[FIG.49]



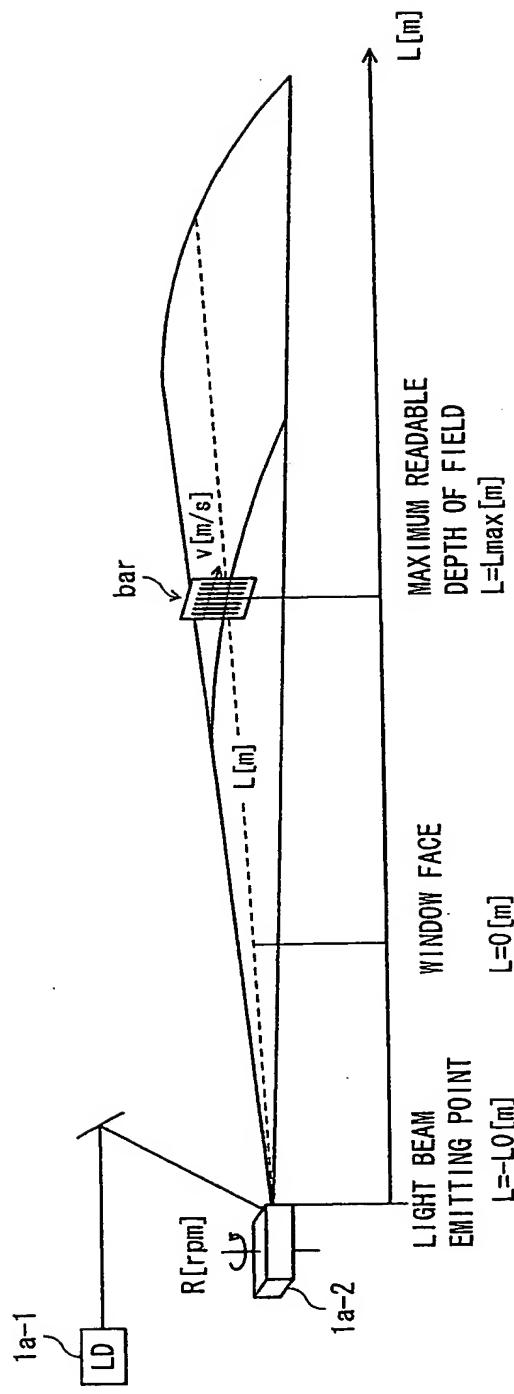
[FIG.50]



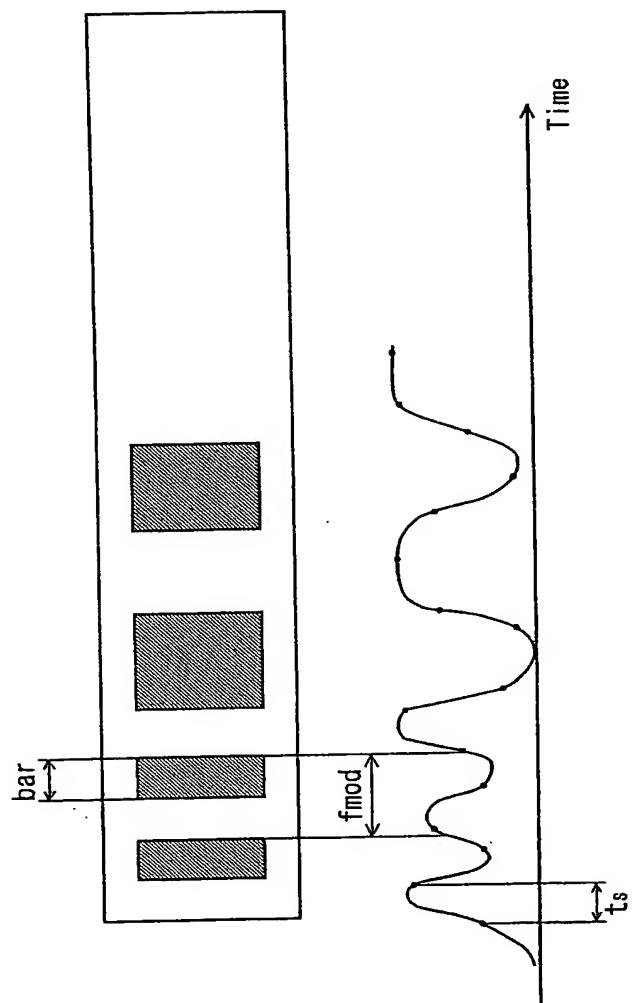
[FIG.51]



[FIG.52]



[FIG.53]



[FIG.54]

(a)

fmod[kHz]

fs/fmod		v[m/s]							
mag	bar[μ s]	200	300	400	500	600	700	800	900
0.6	198	505	758	1010	1263	1515	1768	2020	2273
0.5	165	606	909	1212	1515	1818	2121	2424	2727
0.4	132	758	1136	1515	1894	2273	2652	3030	3409
0.3	99	1010	1515	2020	2525	3030	3535	4040	4545

(b)

fs=5MHz

fs/fmod		v[m/s]							
mag	bar[μ s]	200	300	400	500	600	700	800	900
0.6	198	9	6	4	3	3	2	2	2
0.5	165	8	5	4	3	2	2	1	1
0.4	132	6	4	3	2	2	1	1	1
0.3	99	4	3	2	1	1	1	1	1

(c)

fs=10MHz

fs/fmod		v[m/s]							
mag	bar[μ s]	200	300	400	500	600	700	800	900
0.6	198	19	13	9	7	6	5	4	4
0.5	165	16	11	8	6	5	4	4	3
0.4	132	13	8	6	5	4	3	3	2
0.3	99	9	6	4	3	3	2	2	2

(d)

fs=20MHz

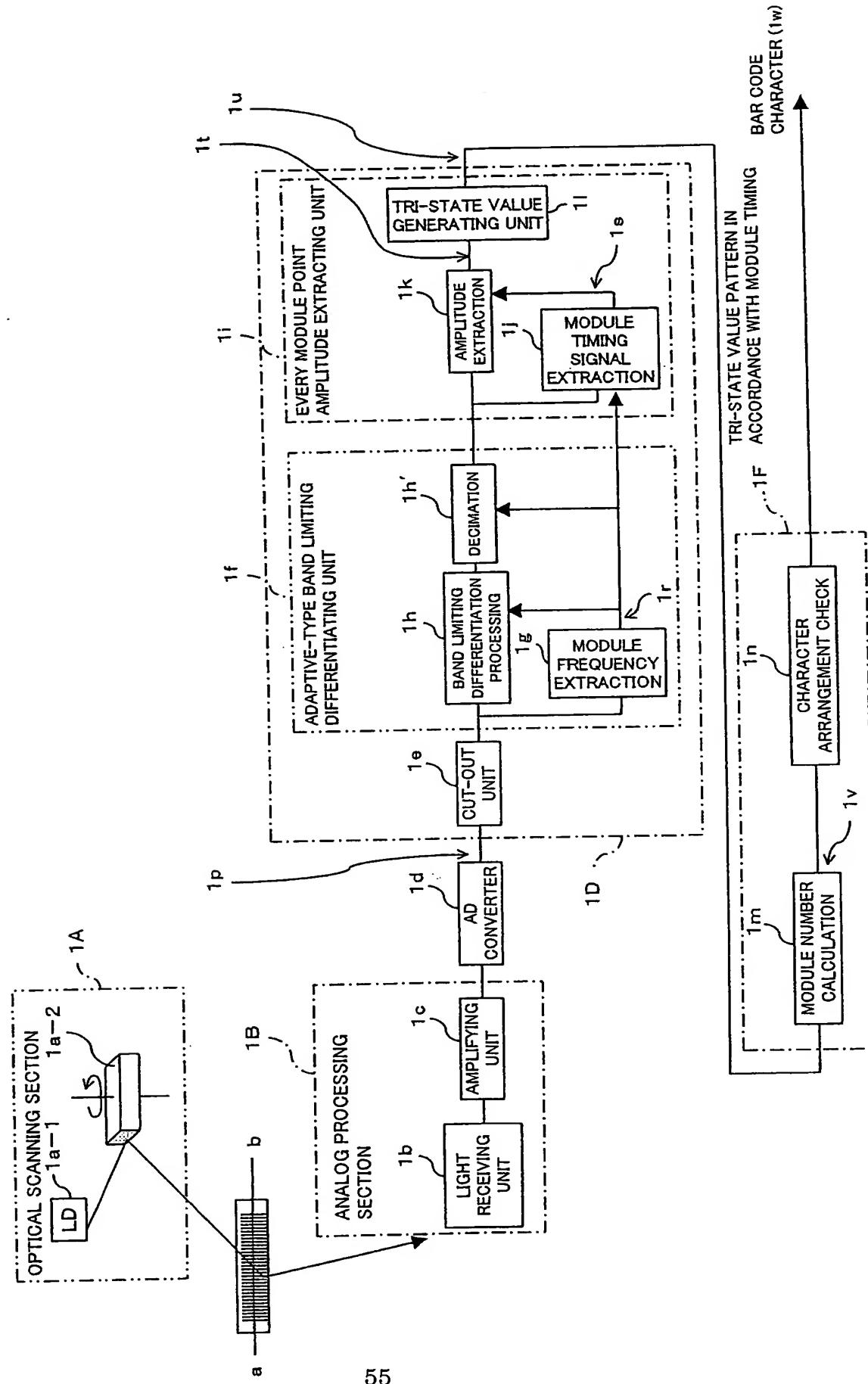
fs/fmod		v[m/s]							
mag	bar[μ s]	200	300	400	500	600	700	800	900
0.6	198	39	26	19	15	13	11	9	8
0.5	165	33	22	16	13	11	9	8	7
0.4	132	26	17	13	10	8	7	6	5
0.3	99	19	13	9	7	6	5	4	4

(e)

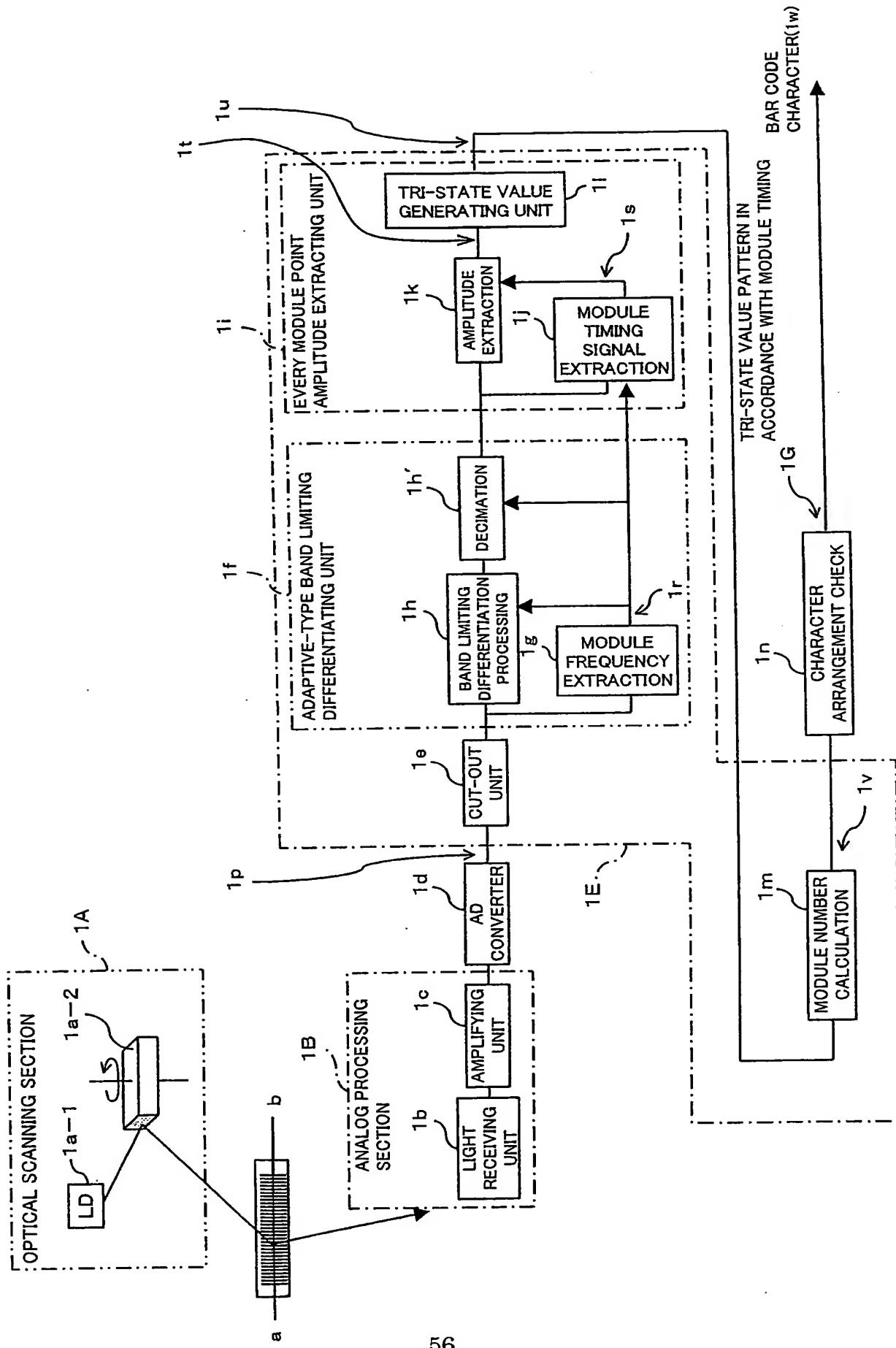
fs=40MHz

fs/fmod		v[m/s]							
mag	bar[μ s]	200	300	400	500	600	700	800	900
0.6	198	79	52	38	31	28	22	19	17
0.5	165	66	44	33	26	22	18	16	14
0.4	132	62	35	26	21	17	15	13	11
0.3	99	39	26	19	15	13	11	9	8

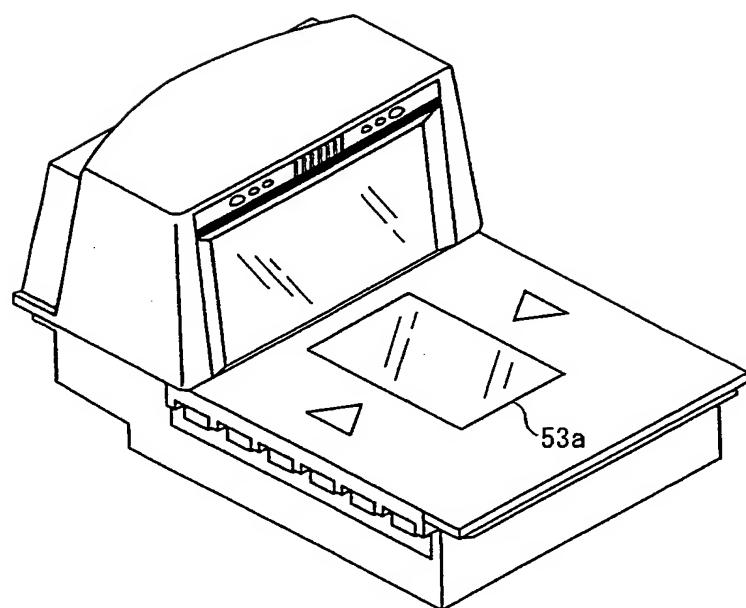
[FIG.55]



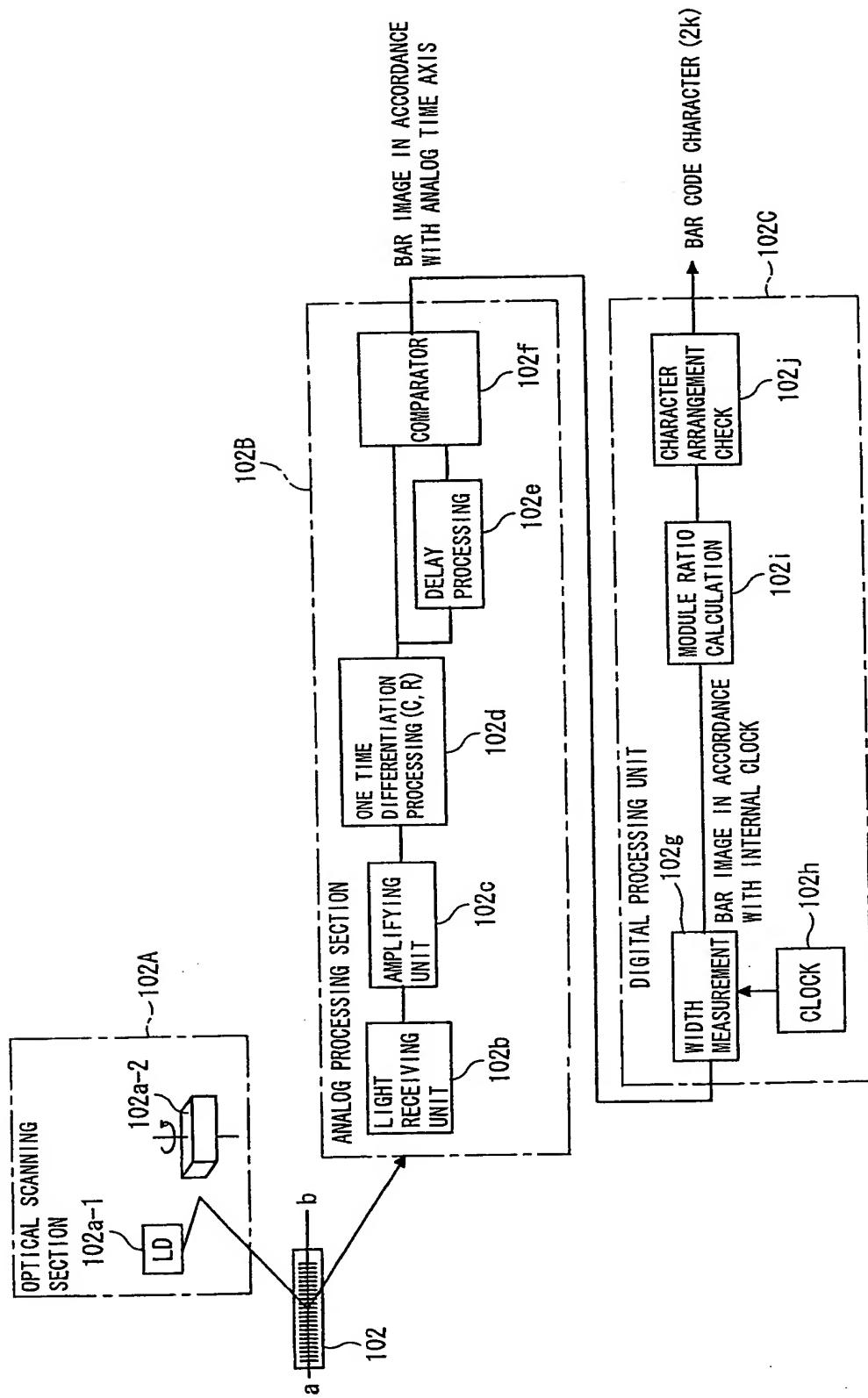
[FIG.56]



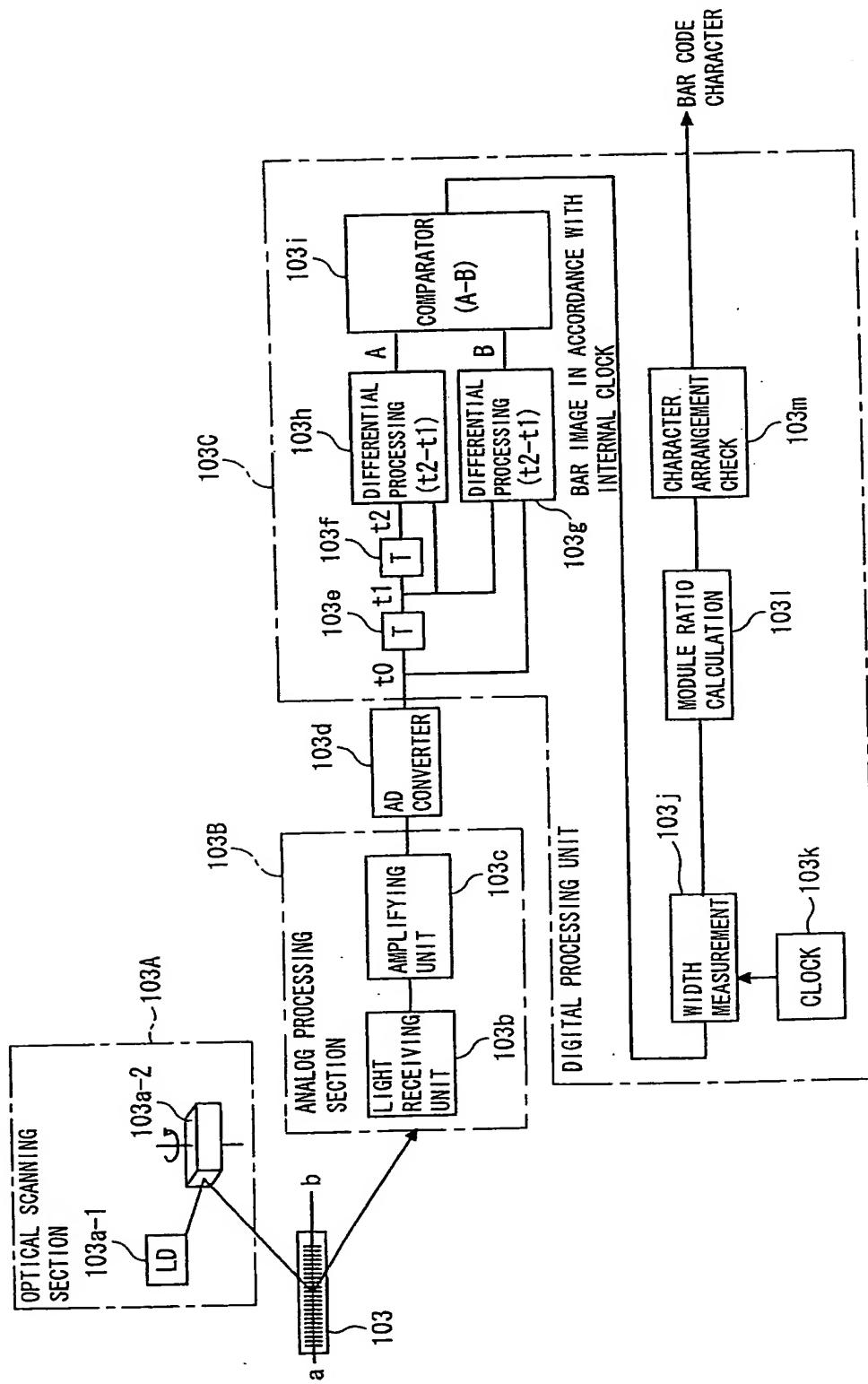
[FIG.57]



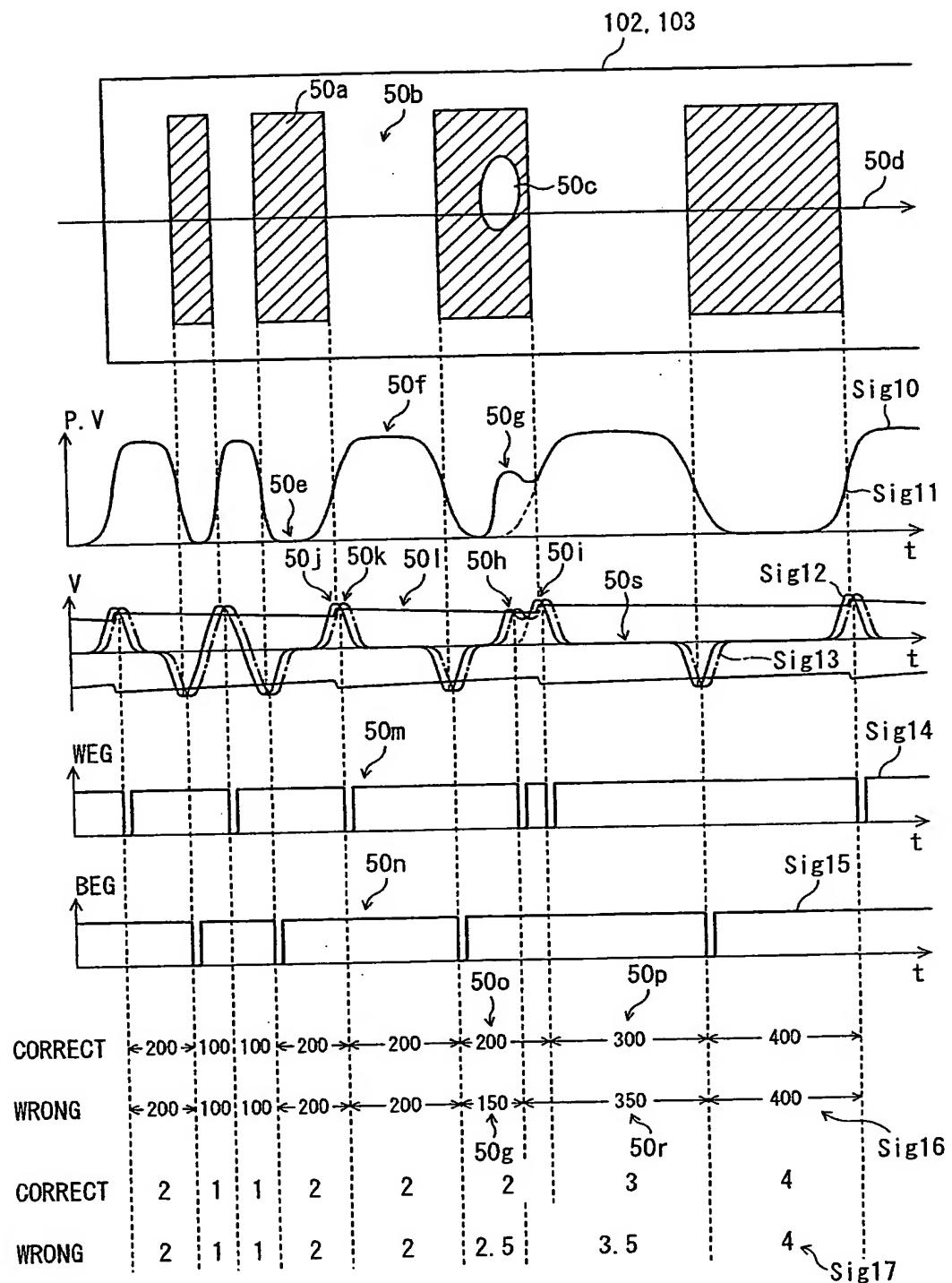
[FIG.58]



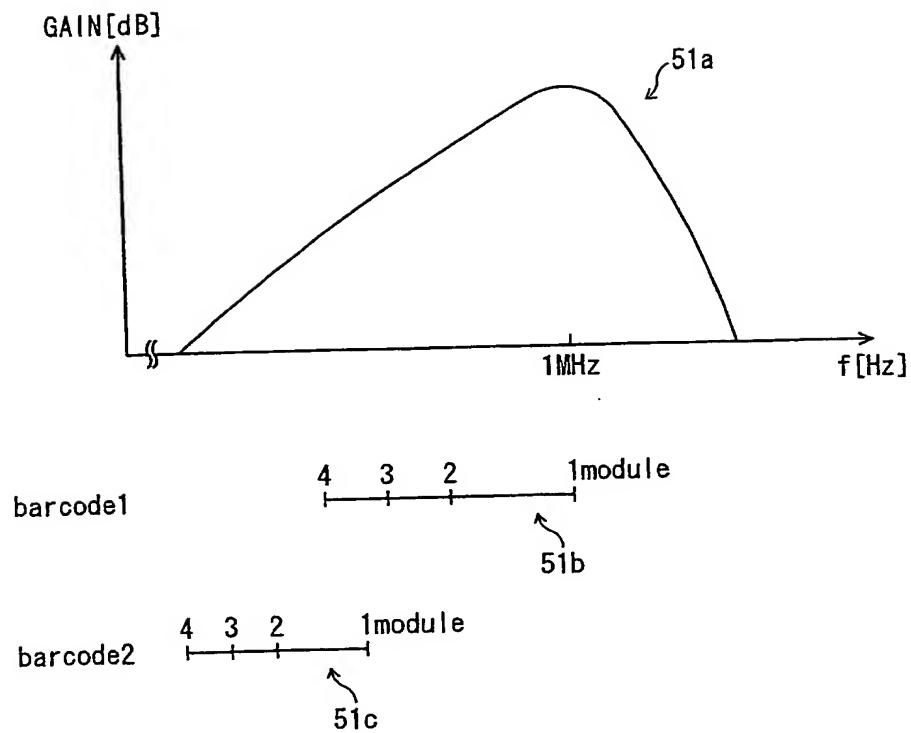
[FIG.59]



[FIG. 60]



[FIG.61]



[FIG.62]

